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No. 9

Comparison of Hansen's Tables as modified by Professor Newcomb and Delaunay's New Tables with Observations made at Greenwich with the Transit-Circle and Altazimuth for the Year 1914.

(Communicated by the Astronomer Royal.)

The following table is based on the observations of the Moon's limbs and the crater Mösting A made with the transit-circle and altazimuth. A mean error has been found for each day from the combined results of limb and crater observations with the two instruments.

As is well known, the *Nautical Almanac* gives the Hansen-Newcomb positions of the Moon. The differences "*Nautical Almanac* minus Delaunay" in R.A. and N.P.D. have been interpolated from the table in *M.N.*, lxxiii. 6, pp. 412, 413. The resulting errors of *Nautical Almanac* and Delaunay in longitude and E.N.P.D. have been found with the aid of the table of P, Q, R, S factors in the Appendix to the *Greenwich Observations for 1836*.

The observations of N.P.D. were reduced with the *N.A.* value of the parallax, not with the Delaunay value; the latter is in the mean $0''.47$ greater. The *N.A.* value of the semidiameter was also employed, which is in the mean $0''.49$ greater than the Delaunay value.

	Date and Approx. Hour of Meridian Passage.		Error of R.A.		Error of N.P.D.		Error of Longitude.		Error of E.N.P.D.	
			N.A.	Delaunay.	N.A.	Delaunay.	N.A.	Delaunay.	N.A.	Delaunay.
	d	h	s	s	"	"	"	"	"	"
Jan.	5	7	-0'87	-0'17	+6'0	+1'9	-14'0	-3'0	+1'0	+0'9
	6	7	-1'05	-0'32	+5'5	+1'9	-15'9	-4'9	+0'4	+0'4
	14	15	-0'67	-0'05	-4'4	-3'3	-10'8	-1'9	-0'5	-2'8
Feb.	1	5	-0'95	-0'28	+5'6	+1'3	-15'0	-4'3	-0'1	-0'3
	2	5	-1'05	-0'34	+3'4	-0'6	-15'3	-4'4	-2'0	-2'2
	3	6	-1'07	-0'32	+4'0	+0'6	-15'5	-4'5	-0'5	-0'7
	4	7	-1'10	-0'31	+2'4	-0'3	-15'2	-4'1	-0'9	-1'2
	5	8	-1'15	-0'33	+3'1	+1'3	-15'6	-4'5	+1'1	+0'7
	6	9	-1'20	-0'36	-0'7	-1'4	-15'9	-4'7	-1'1	-1'5
	9	12	-0'90	-0'16	-3'9	-2'3	-13'2	-2'8	-0'3	-1'6
	11	13	-0'75	-0'13	-3'4	-1'7	-11'6	-2'4	+1'1	-0'8
Feb.	27	2	-1'01	-0'43	+1'5	-2'6	-14'5	-4'9	-4'6	-4'9
Mar.	10	11	-0'96	-0'24	-3'5	-1'5	-14'4	-3'8	+1'8	-0'1
	12	13	-0'76	-0'11	-6'6	-5'1	-13'1	-3'5	-1'5	-4'0
	16	17	-0'60	-0'01	-2'1	-2'7	-8'4	-0'6	-0'5	-2'6
Mar.	31	3	-1'12	-0'34	+6'3	+4'3	-16'1	-5'4	+3'1	+3'3
Apr.	1	4	-1'12	-0'27	+1'9	+1'0	-15'0	-3'7	+0'6	+0'7
	2	5	-1'13	-0'22	+0'5	+0'7	-15'0	-2'9	-0'3	-0'3
	3	6	-1'20	-0'27	-1'9	-0'7	-16'1	-3'7	-0'3	-0'3
	4	7	-1'07	-0'15	-4'1	-2'0	-15'1	-2'4	-1'2	-1'6
	6	9	-0'95	-0'14	-3'6	-0'6	-14'2	-2'1	+1'3	+0'1
	7	10	-1'03	-0'30	-5'6	-2'4	-16'3	-5'0	+0'6	-0'5
	8	11	-0'96	-0'27	-5'7	-2'7	-15'5	-4'8	+0'5	-0'9
	10	12	-0'82	-0'16	-4'3	-2'7	-12'7	-3'2	+0'4	-1'7
	11	13	-0'68	-0'04	-4'6	-4'0	-10'6	-1'8	-1'4	-3'6
	12	14	-0'68	-0'06	-1'3	-1'6	-9'4	-1'2	+0'8	-1'4
	14	16	-0'79	-0'21	-0'3	-2'0	-10'5	-2'8	-0'1	-2'0
	15	17	-0'69	-0'13	-0'8	-3'1	-9'1	-1'4	-1'6	-3'3
	17	19	-0'66	-0'17	+1'7	-1'6	-9'4	-1'9	-0'8	-2'2
	18	20	-0'53	-0'06	-0'1	-3'7	-7'2	+0'4	-2'6	-3'8
Apr.	27	1	-0'92	-0'21	+3'8	+0'7	-13'0	-2'9	+1'2	+0'1
	28	2	-0'96	-0'21	+5'3	+3'2	-13'3	-3'1	+3'8	+2'9
	29	3	-1'01	-0'22	+1'4	+0'4	-13'4	-2'9	+0'8	+0'3
May	1	5	-1'06	-0'19	-2'7	-1'3	-14'7	-2'8	-0'1	-0'8
	2	6	-1'12	-0'23	-2'8	-0'1	-15'8	-3'1	+1'1	+0'7
	3	7	-0'96	-0'07	-4'5	-0'8	-14'5	-1'2	0'0	-0'5

Date and Approx. Hour of Meridian Passage.		Error of R.A.		Error of N.P.D.		Error of Longitude.		Error of E.N.P.D.	
		N.A.	Delaunay.	N.A.	Delaunay.	N.A.	Delaunay.	N.A.	Delaunay.
May	d h	s	s	"	"	"	"	"	"
	4 8	-1'06	-0'19	-3'0	+1'3	-15'7	-2'1	+2'8	+2'2
	13 16	-0'71	-0'16	+1'2	-1'4	-9'7	-1'9	-0'2	-1'7
	16 19	-0'59	-0'15	+3'0	-0'7	-9'2	-1'8	-0'2	-1'4
	17 19	-0'64	-0'22	+2'9	-0'9	-9'9	-2'7	-0'9	-2'1
June	1 6	-0'85	-0'07	-5'0	-1'1	-13'6	-1'4	+0'3	-0'6
	3 8	-1'00	-0'19	-5'6	-1'4	-15'9	-3'2	+0'7	-0'2
	4 9	-0'91	-0'11	-4'2	-0'7	-13'9	-1'8	+1'0	-0'1
	14 18	-0'76	-0'30	+3'7	0'0	-11'9	-4'1	-1'1	-1'8
	16 19	-0'51	-0'04	+3'5	-0'2	-8'4	-0'5	+0'3	-0'4
	17 20	-0'72	-0'22	+2'8	-0'7	-10'8	-2'7	-1'3	-1'8
	18 21	-0'91	-0'34	+3'6	+0'3	-13'6	-4'7	-1'1	-1'4
	19 21	-0'86	-0'23	+4'4	+1'4	-12'8	-3'5	+0'7	+0'4
June	25 2	-1'04	-0'25	-2'0	-0'5	-14'5	-3'5	+1'2	+0'3
	26 3	-0'98	-0'21	-1'6	+0'7	-13'8	-2'7	+2'5	+1'5
	27 3	-1'06	-0'32	-2'9	+0'1	-15'5	-4'3	+2'4	+1'6
	28 4	-0'74	-0'02	-3'6	-0'2	-11'5	-0'4	+0'7	-0'1
	29 5	-0'70	+0'05	-2'4	+1'2	-10'6	+1'2	+2'0	+0'9
	30 6	-0'92	-0'13	-6'0	-2'2	-15'0	-2'7	-0'1	-1'3
July	2 8	-0'97	-0'10	-3'7	-1'0	-14'3	-1'7	+1'1	-0'5
	4 9	-0'96	-0'07	+0'1	+0'3	-12'7	-0'9	+2'4	+0'5
	6 12	-0'93	-0'13	+0'6	-1'8	-12'3	-1'6	0'0	-1'9
	7 13	-0'99	-0'27	+3'3	+0'1	-13'8	-3'6	+1'1	-0'5
	9 14	-0'76	-0'17	+5'5	+1'6	-12'1	-2'8	+1'8	+0'8
	11 16	-0'82	-0'33	+5'5	+1'8	-13'4	-5'2	+0'4	-0'2
	17 20	-1'03	-0'35	+4'9	+2'6	-14'9	-5'3	+1'3	+1'3
July	26 3	-0'83	-0'17	-7'4	-4'3	-14'4	-4'0	-1'9	-3'0
	30 6	-0'99	-0'08	-3'8	-2'4	-14'4	-1'8	+0'4	-2'0
Aug.	2 9	-1'07	-0'16	+0'7	-1'5	-14'2	-2'1	+0'6	-1'5
	3 10	-0'99	-0'17	+3'2	0'0	-13'6	-2'3	+1'6	-0'3
	5 12	-0'92	-0'27	+3'3	-0'7	-13'4	-3'5	-0'6	-1'8
	7 14	-0'73	-0'17	+5'4	+1'6	-12'1	-2'9	+0'9	+0'5
	10 16	-0'63	-0'14	+4'1	+1'0	-10'2	-2'3	+0'2	+0'1
	11 16	-0'55	-0'05	+3'6	+0'8	-8'8	-1'0	+0'5	+0'5
	12 17	-0'91	-0'39	+5'0	+2'5	-14'0	-6'1	+0'4	+0'5
	13 18	-0'95	-0'41	+2'9	+0'8	-13'5	-5'7	-0'9	-0'8
	16 20	-1'05	-0'33	+1'5	+1'2	-13'9	-4'4	+1'3	+1'1
	17 21	-1'33	-0'59	-4'7	-4'2	-18'1	-8'2	-3'1	-3'5

Date and Approx. Hour of Meridian Passage.		Error of R.A.		Error of N.P.D.		Error of Longitude.		Error of E.N.P.D.	
		N.A.	Delaunay.	N.A.	Delaunay.	N.A.	Delaunay.	N.A.	Delaunay.
d	h	s	s	"	"	"	"	"	"
Aug.	29 7	-0'98	-0'10	+0'5	-1'2	-13'0	-1'4	+0'9	-1'2
	30 8	-0'94	-0'08	+0'6	-2'2	-12'6	-0'9	-0'4	-2'3
Sept.	1 10	-0'85	-0'13	+4'3	+0'5	-12'6	-1'9	+1'0	0'0
	2 11	-0'76	-0'11	+4'6	+0'6	-11'9	-1'7	+0'9	+0'1
	3 12	-0'66	-0'08	+5'5	+1'7	-11'1	-1'7	+1'6	+1'2
	5 13	-0'73	-0'21	+6'1	+2'6	-12'5	-3'9	+1'2	+1'1
	6 14	-0'71	-0'21	+5'0	+1'8	-11'7	-3'6	+0'4	+0'4
	7 14	-0'54	-0'04	+4'3	+1'3	-9'0	-1'0	+1'1	+1'0
	9 16	-0'71	-0'20	+1'2	-1'4	-9'9	-2'3	-1'7	-2'1
	10 17	-0'84	-0'32	+2'1	-0'2	-11'6	-4'2	-0'4	-1'1
	11 17	-0'92	-0'38	+1'2	-0'7	-12'3	-4'9	-0'4	-1'4
	12 18	-0'88	-0'32	-1'7	-2'9	-11'6	-4'1	-2'1	-3'1
	14 20	-0'94	-0'31	-0'7	+0'1	-12'7	-4'1	+1'4	+0'8
Sept.	25 5	-1'05	-0'35	+2'2	-0'1	-13'8	-4'6	+3'1	+0'2
	27 7	-1'00	-0'30	+2'8	-1'2	-13'8	-3'8	+0'7	-1'8
	28 8	-0'82	-0'12	+6'4	+2'2	-12'6	-2'1	+3'5	+1'7
	29 9	-0'90	-0'22	+5'5	+1'2	-13'9	-3'4	+1'3	+0'2
	30 9	-0'81	-0'16	+7'8	+3'4	-13'8	-3'4	+3'1	+2'4
Oct.	1 10	-0'80	-0'19	+6'0	+1'5	-13'3	-3'2	+1'0	+0'3
	3 12	-0'67	-0'10	+3'9	-0'2	-10'7	-1'3	-0'4	-0'8
	4 12	-0'71	-0'15	+4'9	+1'1	-11'6	-2'5	+0'5	+0'2
	5 13	-0'69	-0'13	+2'7	-0'8	-10'3	-1'5	-1'0	-1'4
	7 14	-0'82	-0'23	+0'4	-2'0	-11'0	-2'6	-2'3	-2'7
	10 17	-0'84	-0'22	-0'1	-0'4	-11'2	-2'9	+0'2	-0'3
	11 18	-1'07	-0'46	-1'6	-1'1	-14'5	-6'3	+0'2	-0'3
Oct.	27 7	-0'89	-0'33	+4'8	-0'2	-13'8	-4'5	+0'1	-1'8
	31 10	-0'69	-0'12	+4'3	-0'1	-11'1	-1'6	-0'1	-0'8
Nov.	2 12	-0'82	-0'23	+3'8	+0'4	-12'3	-3'2	-0'2	-0'7
	3 12	-0'75	-0'14	+2'9	+0'1	-10'8	-1'9	0'0	-0'4
	5 14	-0'86	-0'21	+1'1	-0'3	-11'5	-2'8	0'0	-0'6
	6 15	-0'92	-0'25	+2'4	+1'9	-12'2	-3'3	+2'3	+1'9
	7 16	-0'82	-0'15	+1'3	+1'8	-10'8	-1'8	+2'3	+2'0
	8 17	-0'88	-0'22	-0'8	+0'4	-12'0	-2'9	+1'5	+0'9
	10 18	-0'73	-0'11	-4'1	-1'7	-11'3	-2'1	-0'4	-1'1
	11 19	-0'85	-0'24	-4'4	-1'5	-13'3	-3'9	+0'5	-0'1
	13 21	-0'93	-0'27	-4'7	-1'1	-14'7	-4'2	+1'3	+0'6

Date and Approx. Hour of Meridian Passage.		Error of R.A.		Error of N.P.D.		Error of Longitude.		Error of E.N.P.D.	
		N.A.	Delaunay.	N.A.	Delaunay.	N.A.	Delaunay.	N.A.	Delaunay.
Nov.	d h	s	s	''	''	''	''	''	''
	25 7	-0'73	-0'21	+5'6	+1'2	-12'3	-3'4	+0'9	-0'1
	27 8	-0'73	-0'16	+6'0	+2'0	-12'4	-3'0	+1'3	+0'9
	28 9	-0'87	-0'27	+3'9	+0'1	-13'3	-3'7	-1'2	-1'4
Dec.	1 11	-0'90	-0'28	+2'9	+0'4	-12'6	-3'8	+0'1	-0'4
	4 14	-0'95	-0'32	+0'6	+0'1	-12'6	-4'3	+1'3	+0'4
	5 15	-0'83	-0'21	-0'1	+0'1	-11'2	-2'8	+1'7	+0'5
	10 19	-0'74	-0'15	-4'4	-2'3	-12'0	-3'0	+0'4	-1'2
Dec.	21 4	-0'83	-0'22	+3'5	-1'0	-12'6	-2'7	-0'9	-2'1
	25 7	-0'80	-0'17	+5'9	+1'7	-13'2	-3'0	+1'0	+0'6
	26 8	-0'94	-0'29	+4'7	+0'9	-14'4	-4'2	-0'4	-0'6
	29 10	-1'02	-0'30	+3'2	+1'1	-14'1	-4'2	+0'9	+0'4
	31 12	-1'05	-0'36	-0'1	-0'7	-14'0	-4'8	+0'3	-0'6
Mean for year	...	...	...	...	...	-12'87	-3'05	+0'35	-0'54

The Rotation of the Earth. (Second Paper.)

By H. Glauert, B.A.

In a previous paper on this subject* the errors of position of the Sun, Venus, and Mercury were analysed on the hypothesis that they were due to minute irregularities in the rate of the Earth's rotation, and the resulting curve for the errors of the Earth showed considerable similarity to that of the Moon, as exhibited by Professor E. W. Brown. During the course of the analysis the errors of heliocentric longitude of Venus and the Earth were connected by the equation $\delta l = p\delta L$, in accordance with the above hypothesis, so that the error in position of the Earth remained as the sole unknown. The question arises how far this assumed relation is justified, and whether the similarity of the curves deduced from observations of the Sun and Venus is not merely due to the fact that the Sun's error enters largely into the geocentric error of Venus.

The results of an investigation into this point are given in this paper. In the fundamental equation

$$E = A\delta L + B\delta l$$

the values of δl of each year, as derived from the observations of the Sun and tabulated in the previous paper, have been substituted and the material has then been treated as before. The resulting

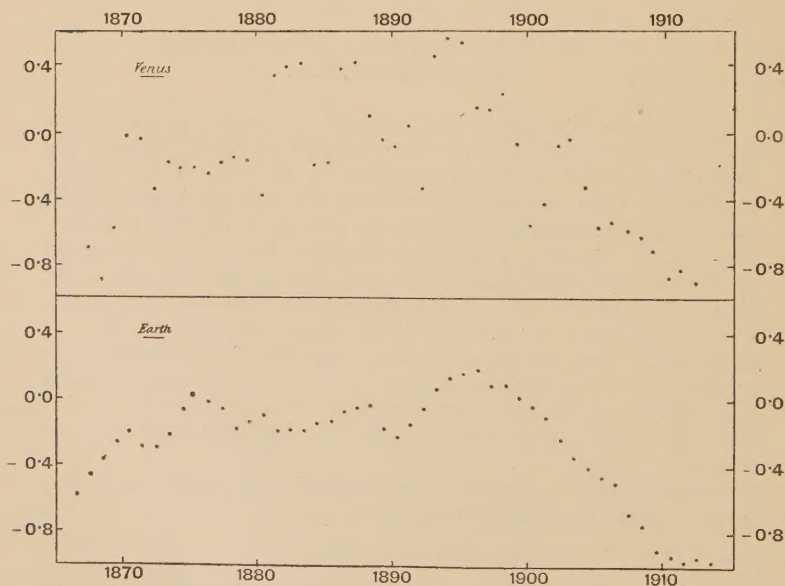
* *R.A.S. Monthly Notices*, vol. lxxv. p. 489.

values of δL for Venus have been multiplied by the factor 0.615 so as to be directly comparable with the errors of longitude of the Earth.

Values of $p\delta L$ of Venus.

	1860+	1870+	1880+	1890+	1900+	1910+
0	...	-0.03	-0.39	-0.09	-0.56	-0.88
1	...	-0.04	+0.33	+0.03	-0.43	-0.83
2	...	-0.35	+0.39	-0.34	-0.08	-0.90
3	...	-0.19	+0.40	+0.45	-0.04	...
4	...	-0.21	-0.20	+0.56	-0.33	...
5	...	-0.21	-0.19	+0.53	-0.57	...
6	...	-0.25	+0.38	+0.15	-0.54	...
7	-0.70	-0.19	+0.41	+0.13	-0.59	...
8	-0.89	-0.16	+0.10	+0.23	-0.63	...
9	-0.58	-0.18	-0.05	-0.07	-0.72	...

The curve obtained for the heliocentric errors of Venus is of a rather irregular nature, but still shows distinct similarity to that of the Earth, which is repeated from the earlier paper.



(1) The general run down of the curve in the last twenty years is quite clearly indicated, while the slope in the first part of the period considered is also shown to some extent.

(2) Although the curve is very irregular between 1880 and 1895, there is nevertheless a certain correspondence with the minor fluctuations of the Earth's curve. In particular the minimum at 1890 is remarkably well shown, and this point is of the greater importance as this minimum is the most clearly defined of the minor oscillations in the Moon's curve.

(3) Another point of importance is the agreement in scale of the two curves shown in the diagram, especially in the latter half of the period, which provides a satisfactory confirmation of the assumption $\delta l = p\delta L$, used in the earlier work.

Summary.—On the assumption that the error in heliocentric longitude of a planet is proportional to its mean motion, three separate determinations of the errors of position of the Earth or Sun have been made. These results showed a satisfactory agreement, and the mean resultant curve closely resembled the curve of the Moon's error of longitude. To obtain further confirmation of the results and to justify the original assumption, the errors of Venus have been examined, and these agree both in the scale and nature of the variations with the adopted hypothesis of slight variations in the rate of rotation of the Earth. A similar analysis of the errors of Mercury would not be justified by the nature and extent of the material available.

Dr. Fotheringham has kindly pointed out a slight error in the last paragraph of the previous paper. The apparent coincidence in the value of $\frac{\delta N}{N}$ in the last ten years with that mentioned in Professor Larmor's paper breaks down, as δN has different meanings in the two papers, being in the one case the increase of δN per century, and in the other the excess of N over its mean value.

Trinity College, Cambridge:
1915 June 24.

The Solar Eclipse of 1916 December 24.
By the Rev. William F. Rigge, S.J.

The magnitude of the solar eclipse of 1916 December 24 is about as small as any that can occur in practice, being only one and one-tenth per cent. of the sun's diameter, according to the American Ephemeris. Its visibility is confined to a small section of unfrequented ocean, about half-way between the Cape of Good Hope and the South Pole. For these two reasons, probably, the Ephemeris does not give a map.

The theoretical aspect of the eclipse, however, is not without interest. The moon's penumbra overlaps the earth only 0.0086 of its radius. In addition to the consequent very oblique and almost horizontal projection of the penumbra on the surface of the

earth, the eclipse occurs near the winter solstice, so that this projection falls upon the Antarctic Circle beyond the South Pole, and progresses westward instead of eastward, as is usually the case, and its northern limit becomes the southern boundary of the eclipse region. And lastly, as some phase of the eclipse occurs at local midnight at some places, there is in very truth an eclipse of the Christmas midnight sun.

The circumstances just mentioned made the construction of the

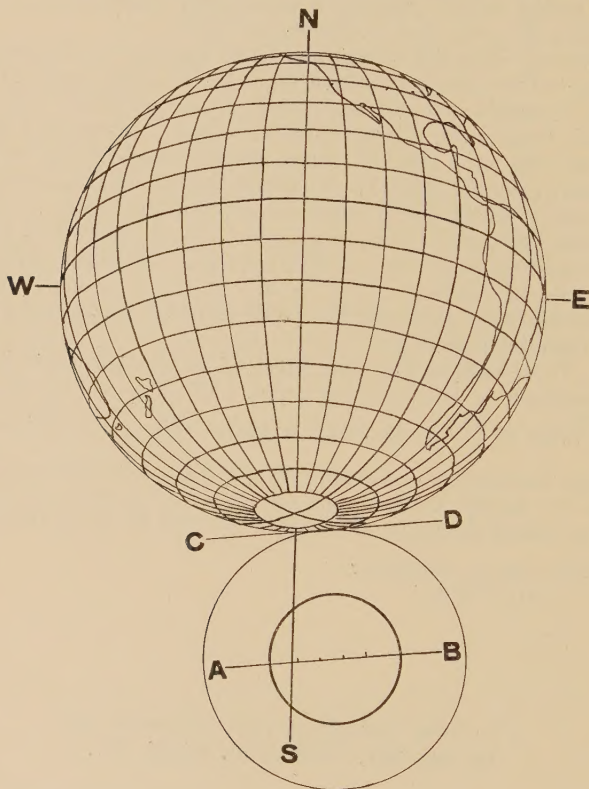
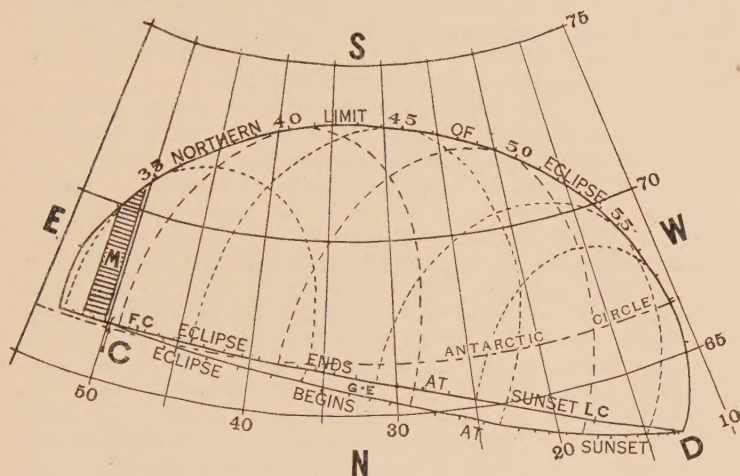


FIG. 1.

eclipse map exceptionally difficult. The reason of this is apparent from fig. 1, which represents the earth as seen from the sun at $8^h 40^m$, Greenwich mean time, when the sun is in the zenith in latitude $23^\circ 25'$ south and in longitude 130° west. The line AB is the path of the centre of the moon and the penumbra, with its position noted at intervals of 10 minutes. The line CD, parallel to AB at the distance of $0.5408 = r =$ the radius of the penumbra, is the northern envelope of the penumbra or the northern limit of the eclipse. Its two points of intersection are only 15° apart on

the earth's disk, and the one towards C is $0^{\circ} 51'$ to the left of the axis of Y. The points of intersection of the penumbral circle at $8^{\text{h}} 46^{\text{m}}.2$, when it overlaps the earth most, are $8^{\circ} 50'$ apart. The points of contact of the penumbral circle at *First* and at *Last Contact* are distant $9^{\circ} 45'$ on the earth's disk. The penumbral circle has been drawn for the time $8^{\text{h}} 46^{\text{m}}.2$ when it is at its least distance from the earth's centre, while the longitude, 130° for the central meridian, corresponds to the time $8^{\text{h}} 40^{\text{m}}$. This difference of 6 minutes of time changes the longitudes a degree and a half. As fig. 1 is intended only to give a general idea of the conditions of this eclipse, this difference is of no consequence. To draw the meridian ellipses to the longitude, $131^{\circ}.5$, would have entailed an unnecessary amount of labour.



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FIG. 2.

Fig. 2 is the eclipse map. N, E, S, W are its cardinal points, with S on top in order to facilitate the comparison of figs. 1 and 2. The numbers 75, 70, 65, to the right, denote the degrees of south latitude, the broken parallel being the Antarctic Circle, while the numbers 50, 40, 30, 20, 10, below, denote the degrees of east longitude. The upper curve, which resembles a semi-ellipse, and which is marked *Northern Limit of Eclipse*, is the projection of the line CD of fig. 1 on the rotating earth. The dotted curves tangent to this Limit Line are successive positions of the penumbra at intervals of 5 minutes, the numbers 35, 40, etc., indicating the minutes after 8 hours, G.M.T. The last dotted curve to the right, however, is drawn for $8^{\text{h}} 59^{\text{m}}$, its point of tangency with the Limit Line being the mark near the number 65.

The two lower lines, *Eclipse begins at Sunset* and *Eclipse ends*

at *Sunset*, need no explanation. The times are indicated to single minutes. The point FC is that of *First Contact* of the penumbra with the earth, LC that of *Last Contact*, and GE that of the *Greatest Eclipse*. The points at which the envelope line, CD, on fig. 1, intersects the earth's disk, are the points C and D on fig. 2. At each of these points four curves originate on ordinary eclipse maps, the Limit Line, the middle line, and both branches of the ovals. At D three of these curves are apparent, the *Northern Limit*, the *Eclipse ends at Sunset*, and the *Eclipse begins at Sunset*. The *Middle of the Eclipse at Sunset* has not been drawn. It would run from D, about midway between the two last-mentioned curves, through the point GE to the point C. At this point, C, the nascent Limit Line runs due east for about four degrees of longitude, and then turns abruptly south. The curves, *Eclipse begins at Sunrise*, the *Eclipse ends at Sunrise*, and the *Middle of the Eclipse at Sunrise*, all practically coincide here with the mentioned nascent portion of the Limit Line.

In $66^{\circ} 35'$ south latitude the sun is in the south horizon at midnight, and one degree higher in the sky for every degree of latitude, as one goes south and approaches the pole; while as one goes north the sun is below the horizon at midnight. Everywhere in east longitude, 50° , there is local midnight at $8^{\text{h}} 40^{\text{m}}$, G.M.T. As the equation of time is only about 10 seconds, apparent and mean times practically coincide. In east longitude, $51^{\circ} 15'$, local midnight occurs at $8^{\text{h}} 35^{\text{m}}$, G.M.T., for which time the first outline of the penumbra is drawn on the map, the dotted curve tangent to the *Northern Limit* line at the number 35 on fig. 2. In this longitude, therefore, for about three degrees of latitude, there is an eclipse of the midnight sun. The midnight sun is also eclipsed within the longitudes of about $51^{\circ} 50'$ to $50^{\circ} 15'$. This space is represented on the map by the shaded portion about the letter M. To the east of $51^{\circ} 50'$, and as far as the Limit Line, the eclipse begins and ends at sunrise on December 25, Christmas morn, a few moments or minutes after midnight.

The eclipse begins, for the earth generally, at $8^{\text{h}} 32^{\text{m}}.4$, G.M.T., at the point of *First Contact*, FC on fig. 2. The penumbra spreads rapidly in all directions except north, so that by $8^{\text{h}} 35^{\text{m}}$ its outline on the earth is shown by the dotted curve mentioned before, which is tangent to 35 on the *Northern Limit* curve. Except for this initial expansion, the penumbra always moves westward (instead of eastward as in ordinary eclipses), so that the eclipse is beginning at this moment at the western part of the dotted curve, which extends from the point of tangency at number 35 to the curve *Eclipse begins at Sunset*. The eclipse ends at the eastern part. The same explanation refers to all the dotted curves. The last one to the right, which, as was said, is drawn for $8^{\text{h}} 59^{\text{m}}$, shows what a change comes over the penumbra in one minute, since at $9^{\text{h}} 0^{\text{m}}.1$ it has shrunk to a point at the *Last Contact*, LC.

The graphic method, which lends itself so well to the construction of ordinary eclipse maps, was altogether unable to cope with the present one, so that recourse had to be had to computation. The method finally pursued was the following:—

In the notation of the American Ephemeris, let ξ and η be the co-ordinates of points of the terrestrial sphere as projected upon the fundamental plane, the radius of this sphere being unity. Let x and y be the co-ordinates of the centre of the penumbra, and r its radius, their values being given in the Ephemeris, at intervals of 10 minutes. The equation of the penumbral circle is then :

$$(x - \xi)^2 + (y - \eta)^2 = r^2.$$

Taking the values of x , y , and r at any given time, and assuming a value of ξ , we can compute η . The latitude ϕ , the hour-angle τ , and the longitude λ are then found from the equations :

$$\begin{aligned}\sin K &= \xi \\ \sin N &= \eta \sec K \\ \sin \phi &= \cos K \sin (N + \delta) \\ \tan \tau &= \tan K \sec (N + \delta) \\ \lambda &= \mu - \tau,\end{aligned}$$

in which K and N are auxiliary angles and μ is the longitude of the central meridian at the time. Successive values of ξ were assumed until $\xi^2 + \eta^2$ began to exceed unity. The plot of the latitudes and longitudes of the points obtained gave the outline of the penumbra on the earth at the given time.

The points of tangency of the penumbral curves with the *Northern Limit* line were computed by finding the co-ordinates ξ and η of points of the line CD, on fig. 1, which were on the normals to AB, at the proper times. These points of tangency then determined the *Northern Limit* itself.

In computing the points at which the eclipse begins and ends at sunrise and sunset, at which the penumbral circle intersects the earth's disk, the terrestrial semi-arc of the common chord was found, and added to and subtracted from the inclination of the line joining their centres. If the resulting angles are called K , then,

$$\xi = \sin K$$

and

$$\eta = \cos K,$$

from which we find

$$\sin \phi = \eta \cos \delta$$

and

$$\tan \tau = \tan K \operatorname{cosec} \delta.$$

No allowance has been made in the eclipse map for refraction. This would most probably shift the curves between C and D about half a degree northward, and all the penumbral curves and the *Northern Limit* line from 7 to 30 minutes of arc also northward.

This might have been done by shifting the latitude lines the proper amount southward on the map. The effect of refraction in longitude is inappreciable. Finally, it may be of service to add that the local times of the eclipse vary from midnight, or a few minutes after it, at the extreme eastern end of the eclipse region, to 9.41 p.m. at the western end. The longest duration of the eclipse anywhere is 17 minutes. This occurs in latitude $65^{\circ} 59'$ and in longitude $32^{\circ} 48'$ on the curve *Eclipse ends at Sunset*. The maximum obscuration is 0.011 of the sun's diameter, and is visible at the point GE, with the sun in the horizon. The maximum altitude of the sun within the eclipse region is less than seven and a half degrees.

The exceptional peculiarities of the present eclipse are the following:—

1. The moon's penumbra is barely more than tangent to the earth's disk.
2. The date is only a few days after the winter solstice, so that the penumbra falls upon the Antarctic Circle beyond the South Pole.
3. As a consequence of the fact last mentioned, the penumbra moves against the diurnal rotation, instead of with it as it does in other eclipses.
4. The eclipse occurs for some places at local midnight, so that there is an eclipse of the midnight sun.
5. This midnight sun eclipsed is the Christmas midnight sun.

Inequalities in the Period of the Eclipsing-Variable RT Persei.

By R. S. Dugan, Ph.D. (Plate 22.)

(Communicated by H. N. Russell.)

The variability of the star B.D. +46° 740 was detected in 1904 by Mme. Ceraski, who found the star faint on a plate taken by Blajko in 1900. Observations of this star have since been made by Blajko, Graff, Tikhoff, Wendell, and Dugan.

During the years 1905-8 the writer made a series* of 904 observations, distributed thickly over the entire light variation and embracing many uninterrupted runs through primary and secondary minima. Each observation is the combined result of sixteen readings with the Pickering polarising photometer.

Blajko and Graff found the period to be $20^h 23^m 11^s$, Tikhoff found a period shorter by one second, while my discussion gave the period $20^h 23^m 10^s.08$, with a very satisfactory representation of all available material.† Two years later I observed through three primary minima, and was much surprised to find them about

* *Contributions from the Princeton Univ. Obs.*, No. 1.

† *Loc. cit.*, p. 15.

seven minutes ahead of the predictions.* This has gone from bad to worse, and at present—about 3000 periods after the zero epoch in 1907—the residual $O - C$ is about -40 minutes.

The Harvard photographic history of this star, which goes back 7700 periods to November 1889, was generously sent me by Professor Pickering. The earliest photographs show a residual of about $+100$ minutes. The average period over the entire known stretch of 10800 periods is therefore nearly a whole second shorter than the shortest of the periods found by the various observers. A satisfactory representation by this shorter period of the observations made from 1906 to 1908 is quite impossible. The minima run off ten minutes in the interval of 700 periods.

The material available for the discussion of the period is collected in Table I. and weighted with great care.

In the record of the Harvard photographs sent me there is given the time of the middle of the exposure to the third decimal of a day and the magnitude usually to a tenth, as estimated by Miss Leavitt. On many of the plates the star was "near edge," and in many cases there is a question mark after the magnitude. There are no multiple-exposure plates of RT Persei—each magnitude is an isolated observation. From a plot of all the observations, both photographic and visual, the average period was found. With this period the approximate shape of the photographic curve was found. The phase of each photographic observation, judged by the brightness of the star, was then found from this approximate photographic light-curve. After the final elements of light-variation were found, the mean photographic curve was again worked out and the times of minima revised. In some cases it was difficult to decide whether the observation was made on the descending or the ascending branch, and in a few cases the residuals are so large as to be of no value. It is clear that the time of eclipse is determined from an isolated photographic measure in this manner with far less accuracy than from a series of observations right through the entire eclipse, for which the shape of the mean light-curve is already known very precisely.

For lack of information, the weighting of the Blajko observations is an uncertain matter.†

The Graff observations are Argelander estimates, and have been published ‡ in detail. I have plotted the observations and weighted the results according to the accuracy with which a symmetrical curve, applied to the plot, apparently determines the time of minimum.

The Wendell observations, § made with an instrument similar to our own, are at least as good as my own. RT Persei was, however, but one among many stars on his observing list, and was seldom followed through more than one branch of the eclipse. I have found in my own work * with our photometer that the observations of one night are sometimes systematically higher than those

* *Loc. cit.*, p. 16.

† *A.N.*, vol. clxvi. p. 155.

‡ *Hamburger Mitteilungen*, No. 8.

§ *Harvard Annals*, vol. lxi. pt. 2.

of another night; that the mean curve of all minima usually fits the plot of each individual minimum quite closely, but for some nights it has to be pushed farther down to fit the points than on other nights. Since the determination of the time of mid-eclipse from observations made on one branch alone requires also a know-

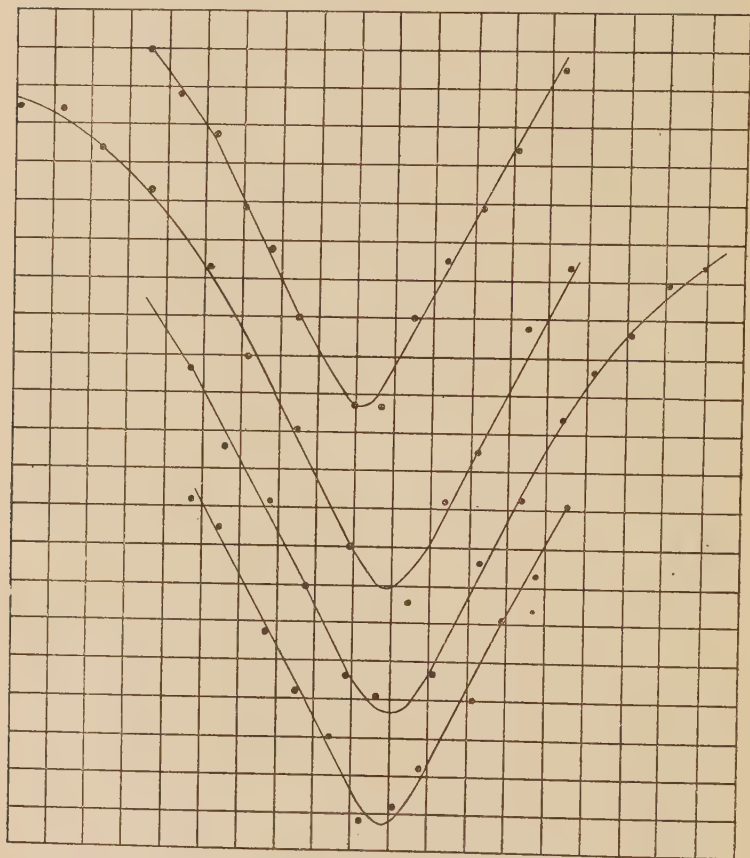


FIG. 1.

ledge of the depth, the uncertainty of the determination is in such cases quite large.

In order to give a convincing idea of how well the times of mid-eclipse are determined from photometric observations made rapidly throughout the eclipse, I have plotted the observations of four such minima in fig. 1. The mean curve is drawn on transparent paper and moved about until it seems to fit all the observations as well as possible. The distance between the co-ordinate lines is one-tenth magnitude vertically, and ten minutes horizontally. It

is apparent that in these cases the mean curve could not be shifted bodily more than a minute or two without ceasing to represent the observations closely. The four minima have been displaced vertically and horizontally in the diagram, so that the points will not be confused.

Minimum +558 was observed through a blue colour screen which I made for the purpose. Minimum +2736 was observed photographically with the 6-inch Neilson camera.

In Table I. the second column contains the Greenwich Helio-centric Mean Time of minimum estimated from the observations made during the minimum. The Epoch E and the calculated time of eclipse C' refer to the elements

$$\begin{aligned} \text{Min. 1907 Oct. } 12^{\text{d}}, 15^{\text{h}} 8^{\text{m}} 34^{\text{s}} \text{ Gr. H.M.T.} + 20^{\text{h}} 23^{\text{m}} 10^{\text{s}} \cdot 08 \text{E} \\ = 2417861 \cdot 63095 \text{ J.D.} + 0^{\text{d}} \cdot 8494222 \text{E.}^* \end{aligned}$$

The abbreviations are self-explanatory.

TABLE I.

J.D.	O. Gr. H.M.T. h m	E.	O - C'. m	Wt.	Source.	Remarks.
1317	18 4	-7704	+101'5	2	H. Pg.	Edge of plate.
1685	13 17'5	7271	+103	$\frac{1}{2}$	,,	"Near edge. Magn. < 11'4."
2085	14 56'5	6800	+ 90'5	3	,,	
2457	15 55	6361	+ 81	3	,,	
4325	12 27'5	4163	+ 47	3	,,	
5041	13 37	3320	+ 26	3	,,	
5086	14 13	3267	+ 34	1	,,	Desc. or asc. ? Average.
5239	10 55	3087	- 14	?	Bl. Pg.	Exposed, 1 ^h 14 ^m .
5368	14 13	2935	+ 22	3	H. Pg.	
5487	12 0	2795	+ 6	1	,,	Near edge.
5615	18 4'5	2644	- 8	1	,,	,,
5666	17 53	2584	+ 30	1	,,	? Poor.
5723	15 20	2517	+ 5	$\frac{1}{2}$	,,	? Edge, very poor.
5746	14 15	2490	+ 34	3	,,	
5751	16 14	2484	+ 14	3	,,	
6169	14 6	1992	+ 8	3	,,	
6175	12 59'5	1985	+ 19	3	,,	

* *Loc. cit.*, p. 15.

TABLE I.—*continued.*

J.D.	O.	E.	O - C'.	Wt.	Source.	Remarks.
	Gr. H. M. T.					
	h m		m			
6376	20 34	1748	+ 23	1	H. Pg	? Elongated images.
6427	19 23	1688	+ 2	3	"	
6444	18 27	1668	- 38	?	"	
6467	17 30	1641	0	2	"	
6519	13 4	1580	+ 1	2	"	Near edge.
6729	8 27	1333	+ 1	1	Bl.	
6734	10 42	1327	- 3	1	"	
6741	5 45	1319	- 5	1	"	
6755	16 16	1302	+ 8	$\frac{1}{2}$	H. Pg.	? Near edge, very poor.
6757	9 14	1300	0	3	Gr.	
6790	12 11	1261	- 3	5	Wen.	5 obs. on asc. br.
6903	11 35	1128	0	$\frac{1}{2}$	Gr.	
6904	8 1	1127	+ 3	5	"	
6921	7 45	1107	+ 1	5	"	
6926	10 10	1101	+ 7	5	"	
6908	14 2	1122	- 1	3	Wen.	4 obs., all asc.
7177	20 16.0	805	- 2.5	15	D.	10 obs., both br.
7183	18 56.5	798	- 4	5	"	9 obs., 2 on desc. br.
7229	15 50	744	- 2	10	Wen.	7 obs., 4 on asc. br.
7235	14 30	737	- 5	5	"	5 obs., all asc.
7230	12 12.7	743	- 2	7	D.	7 obs., both br.
7235	14 34.9	737	+ 1	15	"	14 obs., both br.
7240	16 52.5	731	- 0.5	15	"	13 obs., both br.
7257	16 34.9	711	- 1	15	"	10 obs., both br.
7258	13 0.5	710	+ 1	15	"	15 obs., both br.
7264	11 45.0	703	+ 3.5	5	"	7 obs., all asc.
7274	16 19.0	691	- 0.5	3	"	6 obs., high on desc. br.
7292	12 28.0	670	+ 2	5	"	10 obs., all asc.
7641	15 5	259	- 3	5	Wen.	5 obs., all desc.
7849	17 45.0	- 14	+ 1	10	D.	16 obs., large resid.
7850	14 7.0	- 13	- 0.5	5	"	13 obs., 2 on desc. br.

TABLE I.—*continued.*

J.D.	O.		E.	O-C'.		Wt.	Source.	Remarks.	
	Gr. H.M.T.								
	h	m			m				
7854	20	3'3	-	8	0	12	D.	11 obs., scattered.	
7861	15	8'0		0	0'5	15	,,	19 obs., both br.	
7861	15	9		0	0	10	Wen.	7 obs., 4 desc.	
7873	12	27	+	14	- 6	3	,,	4 obs., high on asc. br.	
7907	11	59'5	+	54	0	6	D.	14 obs., mostly asc.	
7916	20	14'0	+	65	- 0'5	15	,,	14 obs., both br.	
7917	16	37'3		66	- 0'5	15	,,	18 obs., both br.	
7918	13	2'0		67	+	1	15	,,	13 obs., both br.
7922	18	56'5		72	0	7	,,	10 obs., 2 asc.	
8335	14	34		558	- 2	10	D. Blue	17 obs., both br.	
8589	13	57		857	- 7	10	D.	8 obs., 3 desc.	
8589	13	50		857	- 13'5	7	Wen.	6 obs., all asc.	
8600	15	0		870	- 4'5	4	,,	5 obs., 3 asc.	
8600	14	57'5		870	- 7	15	D.	14 obs., both br.	
8707	15	28		996	- 16	3	Wen.	3 obs., all asc.	
8713	14	17		1003	- 9	7	,,	6 obs., 3 on each br.	
8713	14	18		1003	- 8	15	D.	17 obs., both br.	
9102	15	4		1461	- 13	15	,,	14 obs., both br.	
0185	14	50'5		2736	- 46	5	D. Pg.	5 exp., 20 min. each, 1 desc.	
0457	10	27		3056	- 43	5	D.	4 obs., high on asc. br.	
0484	14	50	+	3088	- 41	5	,,	7 obs., large resid.	

The normals, whose grouping is indicated in Table I. by spacing, are given in Table II.

TABLE II.

E.	O-C'.	Wt.	Source.	O-C'.	O-C.
	m			m	m
-7500	+ 102	2	H. Pg.	+ 6	- 5
6580	+ 86	6	,,	+ 3	+ 1
4163	+ 47	3	,,	- 3	+ 6

TABLE II.—*continued.*

E.	O - C'. m	Wt.	Source.	O - C'. m	O - C. m
3300	+ 28	4	H. Pg.	- 10	- 3
3087	- 14	?	Bl. Pg.	- 49	—
2935	+ 22	3	H. Pg.	- 11	- 2'5
2720	- 1	2	„	- 32	—
2500	+ 24	7	„	- 4	+ 6
1988	+ 14	6	„	- 6	+ 6
1658	+ 4	8	„	- 12	- 0'5
1315	- 2	3	Bl.	- 13	- 3
1302	+ 8	$\frac{1}{2}$	H. Pg.	- 3	+ 7
1300	0	3	Gr.	- 11	- 1'5
1261	- 3	5	Wen.	- 13	- 3'5
1107	+ 3	15	Gr.	- 5	+ 3
1122	- 1	3	Wen.	- 9	- 1
804	- 3	20	D.	- 7	- 3
742	- 3	20	Wen.	- 6	- 3
739	0	22	D.	- 3	0
731	- 0'5	15	„	- 3'5	- 0'5
711	- 1	15	„	- 3	- 1
710	+ 1	15	„	- 2	- 1
687	+ 1'5	13	„	- 0'5	+ 2'5
259	- 3	5	Wen.	0	- 3'5
- 14	+ 0'5	15	D.	+ 7'5	+ 1
- 8	0	12	„	+ 7	+ 0'5
0	- 0'5	15	„	+ 6'5	0
+ 2	- 1'5	13	Wen.	+ 5'5	- 1
+ 60	- 0'5	21	D.	+ 7'5	0
66	- 0'5	15	„	+ 7'5	0
69	+ 0'5	22	„	+ 8'5	+ 1
558	- 2	10	D. Blue	+ 12	+ 0'5
857	- 7	10	D.	+ 12	0
860	- 11	11	Wen.	+ 8	- 4
870	- 7	15	D.	+ 12	0
1000	- 11	10	Wen.	+ 10	- 2
1003	- 8	15	D.	+ 13	+ 1
1461	- 13	15	„	+ 14	+ 3'5
2736	- 46	5	D. Pg.	- 2	- 9
+ 3072	- 42	10	D.	+ 7	- 1'5

A linear correction to the epoch and period was found graphically from the residuals $O - C'$. The new average period is $0^s.82$ shorter than the old, and leaves the new residuals, $O - C''$, given in column 5. These residuals are plotted in fig. 2, and the source of each designated by a letter. In considering this plot one should also bear carefully in mind the weights given in Table II.

To explain the steep ascent from $-1400E$ to $+400E$ and the maintaining of this high level to $+3000E$ it is necessary to consider two inequalities. The curve in fig. 2 is the combination of two sine terms, one with a coefficient of 12 minutes and a period of $11880E$ or $27\frac{1}{2}$ years, the other with a coefficient of 5 minutes and a period one-third as long as the other, or $3960E$. The two terms go through their zero values together at $-500E$. Column 6 of Table II. gives the residuals $O - C$ from this curve. The values found for these two inequalities are apparently near the truth.

A question of great interest now is whether the secondary minimum shifts its position in either of these periods. Comparatively few observations have been made during secondary minimum. What material there is has been collected in Table III. C' , C'' are the times of the points midway between primary

TABLE III.

J.D.	O. Gr. H.M.T.	E.	O - C m	O - C'' m	Wt.	Source.
4969	18 53	-3405	+19	-20.5	1	H.Pg.
4998	16 27	3371	+46	+ 7	1	"
6499	14 6	1604	+ 7	- 8	1	"
6787	12 53	1265	0	-10.5	3	Wen.
6792	15 7	1259	- 5	-15.5	3	"
6793	11 27	1258	- 8	-18.5	3	"
7180	19 53	798	+13.5	+ 9.5	5	D.
7220	18 12	755	+22.5	+19.5	3	"
7469	14 53	462	- 3.5	- 3	5	Wen.
7857	19 15	- 5	- 9	- 2	15	D.
7858	15 40	- 4	- 7.5	- 0.5	8	"
7862	21 32	+ 1	-11	- 4	8	"
7863	18 7	+ 2	0	+ 7	15	"
7864	14 10	+ 3	-19.5	-12.5	15	"
0453	15 0	+3051	-25.5	+23	5	"
0459	13 26	+3058	-41.5	+ 7	5	"

minima calculated by the old and the new elements respectively. Removing now the effect of the short inequality—column 4 of Table IV.,—that is, assuming that the position of secondary with reference to the primary does not vary with the short inequality, we obtain residuals R_1 , while the residuals R_2 show the effect of the short inequality alone.

TABLE IV.

E.	O-C". m	Short. m	R_1 . m	Long. m	R_2 . m	Wt.
-3388	- 7	-5	-12	+12	+ 5	2
-1604	- 8	+4.5	- 3.5	+ 7	- 1	1
-1260	-15	+4.5	-10.5	+ 5	-10	9
- 780	+13	+2.5	+10.5	+1.5	+14.5	6
- 462	- 3	+0.5	- 2.5	0	- 3	5
0	- 2.4	-3	- 5.4	- 3	- 5.5	27
0	- 2.8	-3	- 5.8	- 3	- 5.8	30
+3056	+15	+4	+19	- 7.5	+ 4	10

If the shorter inequality is caused by a revolution of the line of apsides, the time of secondary minimum should shift back and forth through a range of 20 minutes. The residuals R_2 should follow the curve drawn out in fig. 3. The weight of the point is given in the figure as well as a letter indicating the source. In considering this figure it should be remembered that the entire drop in secondary minimum is little over a tenth of a magnitude, and would not show at all in any but very careful observations. The photographic estimates to a tenth of a magnitude are of little value in fixing the time of secondary eclipse. My own observations follow the curve approximately. They are at least in the same sense as the curve. I have plotted in fig. 4 the observations made through secondary minimum $+2\frac{1}{2}$ E, which is one of two combined in the point of weight 30. The vertical-magnitude-scale is double that used in fig. 1. The time of secondary minimum is determined with much less accuracy than that of primary minimum. The Wendell point at -1260 E is far from the curve. The observations of the three minima which are combined into this point are plotted in fig. 5. In no case were the observations continued right through the minimum. The determination of the time of minimum is in such cases quite uncertain. Furthermore, it is noticeable in fig. 2 that for some reason the Wendell points nearly all lie below the curve.

Mc

-8000

m
10

+5

0

-5

-10

Mag.
10⁻⁵

10⁻⁶

10⁻⁷

Mag.
10⁻⁵

10⁻⁶

10⁻⁷

The last of the residuals R_1 , at $+3056$ E, makes it improbable that the line of apsides is revolving in the period of the longer inequality.

From the discussion of the observations made in 1905-8 it was found that the stars were prolate.* There is probably some flattening at the poles which is beyond the reach of the observations. The distribution of mass in the stars is also unknown. The prolateness, or ellipticity of the disc when at its maximum area, was found to be 0.02. This amount of prolateness in stars of equal mass and homogeneous would cause the line of apsides to revolve in about the period of the shorter inequality.

The amplitude of the shorter inequality corresponds to an orbital eccentricity of 0.013, and the longitude of periastron, counting from the node in the direction of motion, was apparently about 134° in October 1907. Periastron was in the line of sight about a year earlier. The mean curve in 1907 shows a displacement of the secondary toward the preceding primary, and with less distinctness a slightly longer secondary than primary eclipse. This would be the case if the line of apsides was directed to the line of sight as found from the other evidence. The shallowness of the secondary eclipse prevents an accurate estimate of the duration of the eclipse.

SUMMARY.

The residuals of the primary minima plotted in fig. 2 prove that the average period is shorter than hitherto supposed, and that there exist at least two inequalities in the period. The residuals of the secondary minimum plotted in fig. 3 and the mean curve of the observations made chiefly in 1907 indicate a revolution of the line of apsides in the period of the shorter inequality, caused by the ellipticity of the stars.

One or two minima, both primary and secondary, carefully observed each year for the next ten years, should throw much light upon this very important question.

The new elements are

$$\begin{aligned} 1907 \text{ Oct. } 12^d, 15^h 1^m.6 \text{ Gr. H.M.T.} + 20^h 23^m 9^s.26E \\ + 12^m \sin (0^\circ.030E + 15^\circ) + 5^m \sin (0^\circ.091E + 45^\circ) \\ = 2417861.6261 \text{ J.D.} + 0^d.8494127E + 0^d.0083 \sin (0^\circ.030E + 15^\circ) \\ + 0^d.0035 \sin (0^\circ.091E + 45^\circ) \end{aligned}$$

and the new period

$$\begin{aligned} P = 20^h 23^m 9^s.26 + 0^s.38 \cos (0^\circ.030E + 15^\circ) \\ + 0^s.47 \cos (0^\circ.091E + 45^\circ). \end{aligned}$$

* *Loc. cit.*, p. 39.

The ephemeris of primary minima for 1915 in Gr. H.M.T. is as follows:—

Epoch.	d	h m
+3105	Jan. 1	1 24.3
3141	Feb. 0	15 17.9
3174	Mar. 0	16 2.1
3210	Apr. 0	5 55.9
3246	May 0	19 49.6
3282	June 0	9 43.4
3318	July 0	23 37.1
3354	Aug. 0	13 30.8
3390	Sept. 0	3 24.5
3426	Oct. 0	17 18.3
3462	Nov. 0	7 12.0
3498	Dec. 0	21 5.9
	1916.	
+3534	Jan. 0	10 59.6

Princeton University Observatory :
1915 May 20.

Inequalities in the Period of the Eclipsing-Variable Z Draconis.
By R. S. Dugan, Ph.D.

(Communicated by H. N. Russell.)

This star is B.D. +73° 533, and was found to be a variable by Mme. Ceraski by comparison of plates taken by Blajko.* It appears on a great many plates taken at Harvard, the earliest minimum having been recorded in 1890. The Harvard material has been kindly placed at my disposal in manuscript. It has been utilised in the same manner as the observations of RT Persei.† Some of these observations were rejected on account of their large residuals. Several minima were observed visually, in 1903, by Blajko,‡ and the estimated times published. Miss Whitney observed one minimum in 1903 with a Rumford photometer.§ Reed and Daniel observed seven minima in 1903 with a Rumford photometer attached to the 23-inch Princeton telescope.|| Their observations are very numerous, but the artificial star seems to have varied in intensity, resulting in a variable shape of the curve. Nijland has published¶ the times of nineteen minima observed by

* *A.N.*, vol. clxi. p. 159.

† *A.N.*, vol. clxii. p. 383.

| *A.J.*, vol. xxiii. p. 188.

† *M.N.*, vol. lxxv. p. 692.

§ *Pop. Ast.*, vol. xi. p. 428.

¶ *A.N.*, vol. clxxvi. p. 169.

him in the years 1905-7. Graff* has published in detail the observations of five minima. Wendell's† observations are also available in detail, enabling me to estimate for myself the times of deepest phase.

My own observations were begun in 1905 and completed in 1909.‡ They number 1149 results from sixteen settings each, and cover the light-curve thickly. In the discussion of the observations, I found it impossible to represent the older observations closely with linear elements, but contented myself with such elements for lack of anything surely better, and because no sensible error was introduced during the short interval over which the major portion of my observations extended. The elements§ I used were—

$$\text{Min. 1909 Mar. } 22^{\text{d}} 15^{\text{h}} 10^{\text{m}}.4 \text{ Gr. H.M.T.} + 1^{\text{d}} 8^{\text{h}} 34^{\text{m}} 40^{\text{s}}.95 \text{ E} \\ = 2418388.6322 \text{ JD} + 1^{\text{d}}.3574184 \text{ E},$$

agreeing closely with Graff's elements, but having a period two seconds shorter than the one found by Blajko.

A year and a half after completing my discussion of this star, I observed an eclipse six minutes later than the predicted time. Still a year later the residual was again about six minutes.

All the material available for a discussion of the period is collected in Table I., the arrangement of which is the same as that of the corresponding table in the discussion of RT Persei. C' is calculated with the linear elements just given.

TABLE I.

J.D.	O. Gr.H.M.T. h m	E.	O - C'. m	Wt.	Source.	Remarks.
1487	11 16.5	-5084	-68	$\frac{1}{2}$	H. Pg.	
2859	20 7.5	4073	-41	2	,,	
4392	8 50 :	2944	-33 :	?	Bl. Pg.	
4734	11 12	2692	+ 7	$\frac{1}{2}$	H. Pg.	Near edge.
5152	13 1.5	2384	- 6	1	,,	
5160	17 7	2378	+31.5	$\frac{1}{2}$	,,	
5376	12 13	2219	-17	1	,,	Near edge.
5392	19 17	2207	- 9	2	,,	
5414	13 15.5	2191	+34.5	$\frac{1}{2}$	,,	
5502	18 3	2126	-12.5	1	,,	
5513	15 18	2118	+25	$\frac{1}{2}$	,,	
5658	20 33.5	2011	-10.5	$\frac{1}{2}$	,,	Desc. or asc. ? Average.

* *Hamburger Mitteilungen*, Nr. 11.

† *Harvard Annals*, vol. lxix. pt. 2.

‡ *Contributions from the Princeton Univ. Obs.*, No. 2.

§ *Loc. cit.*, p. 16.

TABLE I.—*continued.*

J.D.	O. Gr.H.M.T. h m	E.	O-C'. m	Wt.	Source.	Remarks.
5520	9 31 :	2113	- 15 :	$\frac{1}{2}$	Bl. Pg.	
5749	19 22	1944	- 4'5	1	H. Pg.	Image faint.
5749	19 26'5	1944	0	1	,	,
5787	18 47'5	1916	- 51'5	1	,	Near edge.
5843	11 24'5	1875	+ 3'5	3	,	
5885	13 13'5'	1844	- 2'5	3	,	
6064	17 25	1712	- 9	1	,	Near edge.
6163	19 45	1639	- 1	2	,	Assume corr. of 1 magn.
6193	16 31	1617	+ 2	15	,	17 exposures.
6200	11 19'5	1612	- 3	9	,	9 exp.
6208	14 53'5	1606	+ 3	9	,	7 exp.
6177	9 35	1629	+ 2	...	Bl.	
6185	13 4	1623	+ 3	...	,	
6192	7 57	1618	+ 3	...	,	
6200	11 24	1612	+ 2	...	,	
6234	9 54	1587	+ 5	...	,	
6224	21 47'5	1594	+ 1	3	H. Pg.	
6193	16 30	1617	+ 1	18	Wen.	10 obs., 2 asc.
6200	11 26	1612	+ 3'5	9	,	8 obs., all asc.
6261	13 14	1567	- 9	3	,	4 obs. high on asc. br.
6322	15 30	1522	+ 6	...	Whit.	
6303	15 18	1536	+ 4	1	R. & D.	
6311	18 46	1530	+ 4	6	,	
6341	15 7	1508	- 3	1	..	
6345	17 5'5	1505	+ 1	1	,	
6379	15 35	1480	- 1	6	,	
6383	17 28	1477	+ 6'5	1	,	
6387	19 10'5	1474	+ 4	1	,	
6414	22 49	1454	+ 7	3	H. Pg.	
6823	12 25	1153	- 9'5	6	Wen.	5 obs. high on asc. br.
6850	16 5	- 1133	- 10	9	,	7 obs., all desc.

TABLE I.—*continued*.

J.D.	O. Gr.H.M.T. h m	E.	O-C'. m	Wt.	Source.	Remarks.
6884	14 33	- 1108	- 9.5	12	Wen.	7 obs., all desc.
6907	16 23	1091	- 9	9	,,	5 obs., all desc.
7021	16 58	1007	- 7	9	,,	5 obs., all desc.
7138	10 53	921	+ 5	...	N.	
7210	9 10	868	- 16	...	,,	
7225	7 49	857	+ 1	..	,,	
7233	11 12	851	- 4	6	Gr.	8 obs., 2 desc.
7237	12 55	848	- 4.5	6	Wen.	5 obs., all asc.
7294	13 10	806	- 6.5	15	,,	6 obs., both br.
7305	9 56	798	+ 2	...	N.	
7317	15 0	789	- 6	...	,,	
7324	9 58	784	- 1	...	,,	
7366	11 52	753	- 3	...	,,	
7370	13 26	750	- 13	...	,,	
7438	10 30	700	- 3	...	,,	
7476	10 38	672	6	...	,,	
7480	12 25	669	- 3	...	,,	
7495	10 40	658	- 9	...	,,	
7525	7 26	636	- 6	...	,,	
7552	11 7	616	+ 1	...	,,	
7582	7 48	594	- 1	...	,,	
7639	8 1	552	- 5	...	,,	
7647	11 29	546	- 7	3	Gr.	10 obs., all desc.
7700	10 4	507	- 2	1	,,	Not sym.
7765	13 51	459	0	6	Wen.	5 obs., all asc.
7769	15 28	456	- 7.5	9	,,	5 obs., all desc.
7788	15 38	442	- 3	2	,,	2 obs., high desc.
7738	10 12	479	- 6	...	N.	
7795	10 45	437	+ 11	...	,,	
7799	12 11	434	- 7	...	,,	
7818	12 25	420	+ 1	9	Gr.	
7844	7 24	401	+ 1	9	..	

TABLE I.—*continued.*

J.D.	O. Gr.H.M.T. h m	E.	O-C'. m	Wt.	Source.	Remarks.
7845	15 53	400	- 4'5	6	Wen.	5 obs., all desc.
8031	15 8	263	- 1	3	,,	'5 obs., all desc.
8187	17 36	148	- 1'5	6	D.	6 obs., 1 desc.
8217	14 18'8	126	- 1'7	15	,,	13 obs., both br.
8236	14 24	112	- 2'5	3	,,	6 obs., all desc.
8259	16 15	95	- 1	3	,,	6 obs., all desc.
8267	19 47	89	+ 3	3	,,	4 obs., all desc.
8278	16 20'5	81	- 1	3	,,	6 obs., all desc.
8327	13 11'7	- 45	+ 2'0	9	,,	13 obs., 4 desc.
8377	18 34'5	- 8	+ 1'5	6	,,	9 obs., all desc.
8381	20 16'9	- 5	- 0'2	12	,,	10 obs., both br.
8384	13 27'7	- 3	+ 1'3	15	,,	12 obs., both br.
8388	15 9'8	0	- 0'7	15	,,	14 obs., both br.
8407	15 13	+ 14	- 3	6	Wen.	6 obs., all desc.
8498	14 0	+ 81	0	5	,,	2 obs.
9041	13 14	+ 481	+ 1	6	,,	5 obs., all asc.
9113	11 53	534	+ 2	1	,,	1 obs.
8973	16 24'6	431	+ 6	12	D.	9 obs., both br.
9041	13 19'7	481	+ 7	15	,,	10 obs., both br.
9322	12 58'5	688	+ 6'5	15	,,	7 obs., both br.
9329	7 55	693	+ 9'5	...	Leh.	
0253	17 42'5	1374	+ 15	9	D.	11 obs., chiefly asc.
0568	15 49	+ 1606	+ 18'5	9	,,	6 obs., 1 desc.

The arrangement of the table of normals is likewise the same as that of the table of normals for RT Persei.

TABLE II.

E.	O-C'. m	Wt.	Source.	O-C''. m	O-C. m
-5084	+68	$\frac{1}{2}$	H. Pg.	-21'5	-20
4073	-41	2	,,	-5	-6'5
2944	-33 :	...	Bl. Pg.	-9	-18
2692	+7	$\frac{1}{2}$	H. Pg.	+28	+17
2150	-2	7	,,	+13'5	+0'5

TABLE II.—*continued.*

E.	O-C. m	Wt.	Source.	O-C. m	O-C. m
2113	-15 :	$\frac{1}{2}$	Bl. Pg.	- 1	-14
1944	- 2'5	2	H. Pg.	+11	- 1
1916	-51'5	1	„	-58	-69'5
1860	+ 0'5	6	„	+13	+ 2
1712	+ 9	1	„	+ 2	- 7
1615	+ 0'8	35	„	+10'5	+ 2'5
1614	+ 3	...	Bl.	+12'5	+ 4'5
1594	+ 1	5	H. Pg.	+10'5	+ 3
1610	+ 0'8	30	Wen.	+10'5	+ 2'5
1522	+ 6	...	Whit.	+ 9	+ 2'5
1504	+ 2	17	R. and D.	+10'5	+ 4'5
1454	+ 7	3	H. Pg.	+15	+10
1141	-10	15	Wen.	- 4'5	- 5
1101	- 9'0	21	„	- 5	- 4'5
1007	- 7'2	9	„	- 4	- 2
882	- 3	...	N.	- 1	+ 2'5
851	- 4	6	Gr.	- 2'5	+ 1
818	- 6'0	21	Wen.	- 5	- 1
775	- 4	...	N.	- 3'5	+ 1
675	- 5	...	„	- 5'5	0
601	- 3	...	„	- 2'5	+ 3'5
540	- 6	4	Gr.	- 8	- 1'5
455	- 4'2	17	Wen.	- 7	0
450	- 0'7	...	N.	- 3'5	+ 3'5
410	+ 1	18	Gr.	- 2	+ 5
400	- 4'5	6	Wen.	- 7'5	- 1
263	- 1	3	„	- 7	+ 0'5
134	- 1'7	21	D.	- 8	- 1
94	0	12	„	- 7	0
45	+ 2'0	9	„	- 5	+ 2
- 3	+ 0'3	48	„	- 7	0
+ 14	- 3	6	Wen.	-11	- 4
81	0	5	„	- 8'5	- 2
500	+ 1'5	8	„	-10'5	- 5
460	+ 6'6	27	D.	- 6	0
688	+ 6'5	15	„	- 8'5	- 2'5
693	+ 9'5	...	Leh.	- 6	0
1374	+15	9	D.	- 7'5	+ 1
+ 1606	+18'5	9	„	- 6'5	+ 3

The times C'' are calculated from new linear elements determined graphically from the residuals $O - C'$.

The plot of the residuals $O - C''$, in the diagram, shows that the period shortened rapidly from about -1700 E to -700 E and has since remained nearly constant. An attempt to represent approximately these residuals by two inequalities resulted in the curve shown in the figure. This curve is the combination of two sine terms, one having a coefficient of ten minutes and a period of 7200 eclipse periods, the other having a coefficient of four minutes and a period of 2880 eclipse-periods. This curve leaves the residuals $O - C$ of Table II. In the diagram I have cut off the curve at -2500 E, as the early residuals are very scattered. There is apparently an excess of negative residuals in this region. Two inequalities of approximately these amplitudes and periods seem clearly to be present.

The secondary minimum of Z Draconis is so shallow—only six or seven hundredths of a magnitude—that little aid in interpreting these inequalities can be expected from it. The material is meagre. The existence of the secondary minimum was but recently discovered, and its importance in a discussion of this character realised still more recently. The mean curve of 1909 showed a slight displacement of the secondary toward the following primary minimum. This determined a least value of the orbital eccentricity, 0.01, about the same as that found for RT Persei. The prolateness of the two stars comprising the Z Draconis system is just about the same as that of the stars in the RT Persei system.* It seems hardly wise to attempt to interpret the inequalities in the period of Z Draconis by means of the secondary minima, until more material is in hand.

In this discussion of the period of Z Draconis, as well as in that of RT Persei, the amplitudes and periods of the inequalities were estimated by inspection, the material in hand not seeming to justify more careful treatment, the object being to see if such inequalities exist in these two systems, if they bear any relation to the time of secondary, and how much these stars should be observed in the future. It seems that Z Draconis as well as RT Persei will bear watching.

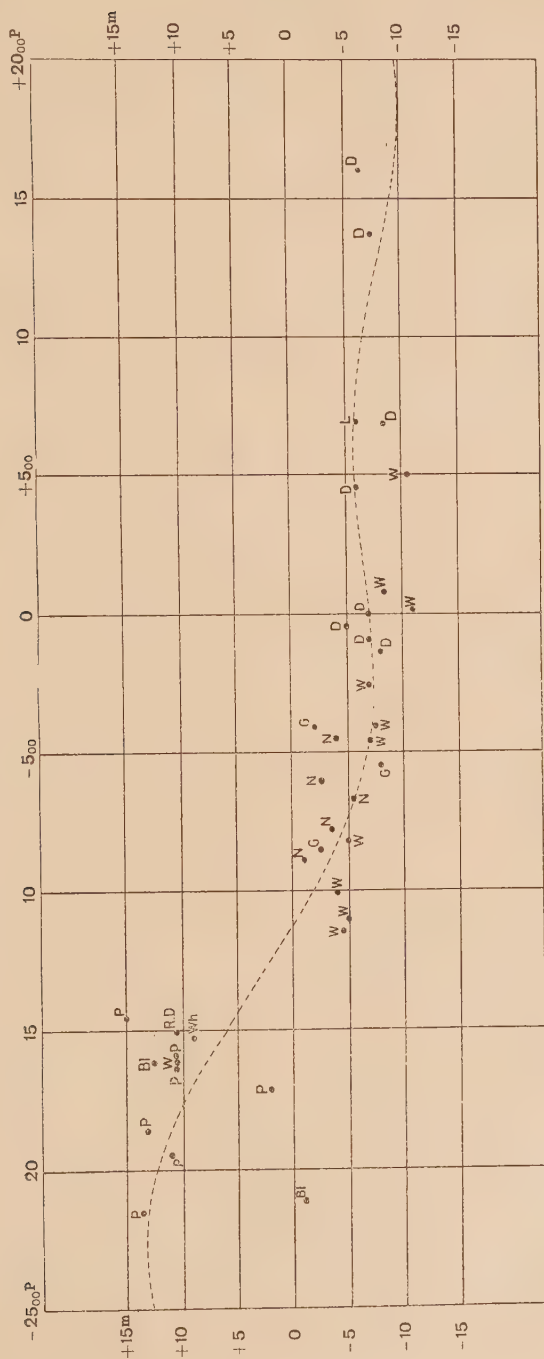
The new elements of Z Draconis are—

$$\begin{aligned} 1909 \text{ Mar. } 22^{\text{d}} 15^{\text{h}} 17^{\text{m}}.8 \text{ Gr. H.M.T.} + 1^{\text{d}} 8^{\text{h}} 34^{\text{m}} 41^{\text{s}}.59 \text{ E} \\ - 10^{\text{m}} \sin(0^{\circ}.050 \text{ E} + 42^{\circ}) + 4^{\text{m}} \sin(0^{\circ}.125 \text{ E} - 4^{\circ}), \\ = 2418388.63736 \text{ JD} + 1^{\text{d}}.3574258 \text{ E} - 0^{\text{d}}.0069 \sin(0^{\circ}.050 \text{ E} + 42^{\circ}) \\ + 4^{\text{m}} \sin(0^{\circ}.125 \text{ E} - 4^{\circ}), \end{aligned}$$

and the period :

$$\begin{aligned} P = 1^{\text{d}} 8^{\text{h}} 34^{\text{m}} 41^{\text{s}}.59 - 0^{\text{s}}.52 \cos(0^{\circ}.050 \text{ E} + 42^{\circ}) \\ + 0^{\text{s}}.52 \cos(0^{\circ}.125 \text{ E} - 4^{\circ}). \end{aligned}$$

* *Loc. cit.*, p. 42.



The Eclipsing-Variable Z Draconis.

The ephemeris for primary eclipses of the coming year is as follows:—

Epoch.	Gr. H.M.T.		Epoch.	Gr. H.M.T.	
	1915	h m		1915	h m
+1555	Jan. 1	10 16·6	1711	Aug. 1	4 28·0
1577	Feb. 0	6 59·4	1733	Sept. 0	1 11·1
1598	Mar. 0	19 8·0	1756	Oct. 1	6 29·0
1621	Apr. 1	0 25·8	1779	Nov. 1	11 47·0
1643	May 0	21 8·4	1801	Dec. 1	8 30·2
1666	June 1	2 26·9		1916	
1688	July 0	23 10·1	+1823	Jan. 0	5 13·4

Princeton University Observatory
1915 May 29.

Occultation Results, 1914. By Maurice E. J. Gheury
and Nora E. Robertson.

The following occultations were observed in 1914 and reduced according to the method described in the *Monthly Notices*, vol. lxxiv. p. 540.

The positions of the stars not given in the *Nautical Almanac* are given below for 1914·0.

No.	Star.	Mean R.A.	Mean N.P.D.	Catalogue.
		h m s	° ' "	
34*	B.D. +20° 2206	8 40 31·66	69 17 29·9	<i>Astr. Gesel.</i> , 1875.
35*	B.D. +20° 2210	8 41 24·61	69 16 20·7	,,
36*	B.D. +20° 2207	8 40 53·60	69 39 46·0	Mean of <i>Astr. Gesel.</i> , 1875, and <i>Edin. Zod. Stars</i> , 1900.
37*	B.D. +20° 2216	8 42 30·97	69 45 45·7	<i>Astr. Gesel.</i> , 1875.
42*	B.D. +27° 914	5 50 15·75	62 17 57·6	,,
	(W.B.(2) V 1531)			
46	B.D. +26° 731	4 33 10·61	63 13 47·8	,,
47	B.D. +23° 1863	7 54 35·38	66 34 55·6	,,

The values of $\Delta\alpha$, $\Delta\delta$ were calculated from Bessel's *Day Numbers* in the usual way.

TABLE I.

No.	Date.	Time.	Accuracy.	Star.	Mag.	Dis. or Reap.	ϕ .	Posi- tion.†
	1914.	h m s	s					
30	Feb. 3	5 1 8.1	± 0.5	ϵ Arietis (mean)	4.6	D	81°	D
31	Mar. 10	15 27 38.8	± 0.6	ρ Leonis	3.8	D	55	B
32	Apr. 7	12 33 54.8	± 1.4	56 Leonis	6.1	D	89	B
33	29	8 29 36.3	± 0.9	136 Tauri	4.6	D	43	B
34*	May 2	9 55 6.8	± 1.1	B.D. + 20° 2206	8.6	D	88	B
35*	2	10 21 25.5	± 0.9	B.D. + 20° 2210	8.2	D	62	B
36*	2	10 42 19.8	± 0.9	B.D. + 20° 2207	8.2	D	13	B
37*	2	11 12 51.9	± 1.0	B.D. + 20° 2216	8.1	D	43	B
38	4	12 11 53.9	± 1.0	49 Leonis	5.7	D	85	B
39	16	14 57 55.5	± 0.8	ι Aquarii	4.4	R	66	D
40	June 4	11 37 33.9	± 0.8	83 Virginis	5.6	D	20	B
41	Aug. 16	12 37 38.4	± 0.8	136 Tauri	4.6	R	89	C
42*	16	13 31 3.5	± 0.7	B.D. + 27° 914	7.5	R	76	C
43	Sept. 1	8 34 11.0	± 0.7	17 Capricorni	5.8	D	72	D
44	10	11 52 42.1	± 0.8	16 Tauri	5.4	R	33	D
45	10	12 22 42.9	± 0.7	20 Tauri	4.1	R	28	D
46	11	12 43 13.2	± 1.0	B.D. + 26° 731	7.0	R	64	D
47	Oct. 12	11 33 1.9	± 1.0	B.D. + 23° 1863	6.7	R	57	D
48	Dec. 1	6 7 5.0	± 0.7	17 Tauri	3.8	D	63	D
49	1	6 38 28.7	± 0.7	20 Tauri	4.1	D	78	D
50	5	7 42 26.4	± 0.8	Δ Geminorum	5.1	R	45	D
51	5	15 51 0.0	± 1.4	B.A.C. 2506	6.3	R	60	D
52	5	16 30 24.8	± 0.8	B.A.C. 2514	6.0	R	71	D
53	21	7 2 39.5	± 0.6	ϵ_2 Aquarii	5.4	D	44	B

Notes.—Nos. 31, 39, 48, 49, 53: instantaneous.

No. 32: from extrapolated rate.

No. 33: observed by Ruth Gheury.

Nos. 34*, 35*, 36*, 37*: faint; difficult.

No. 38: rapid decrease of brightness, then faintly visible for about a second (double: Σ 1450, 6.0 and 9.0 at 2''.4); the time is that of the complete occultation, the position is that of the principal star, hence the discrepancy with the result obtained at Greenwich, where the principal star was observed.

No. 41: gradual.

No. 44: unexpected reappearance. A faint star (missed) had just emerged and was thought to be 16 Tauri; the latter then emerged unexpectedly; allowance was made for this.

No. 45: observed through a nebulous veil.

No. 46: one second was added to the stop-watch reading, as it was observed to "hang" for about that time.

No. 50: from a three-days rate without time-signal checks.

No. 51: moon very bright, difficult; rejected, the time being evidently wrong by several seconds (S.D. - Dist. = - 2''.88).

No. 52: moon very bright, difficult.

* Particulars of these occultations are not given in the *Nautical Almanac*.

† See *Monthly Notices*, vol. lxxiv. p. 541.

TABLE II.

No.	Semi-diameter - Dist.		$= \frac{e}{-x} \times$	$+f \times$	$+y \times$	$+t \times$	$+m \times$	$+n \times$
	From Obs.	at Greenwich Observatory.						
30	-14'70	-15'10	+0'818	-0'478	+0'479	-0'381	+0'330	-0'897
31	-12'54		+0'976	-0'121	+0'122	-0'442	+2'328	-0'994
32	-14'29		+0'864	+0'490	-0'490	-0'518	+0'019	-0'990
33	-9'18	-9'59	+0'596	+0'737	-0'736	-0'381	-0'164	-0'909
34*	-17'25		+0'893	+0'285	-0'283	-0'493	+1'164	-0'942
35*	-14'25		+0'919	-0'166	+0'168	-0'416	+2'293	-0'942
36*	+0'99		-0'077	+0'997	-0'997	-0'194	-2'429	-0'942
37*	-9'46		+0'388	+0'910	-0'909	-0'421	-1'274	-0'943
38	-17'31	-15'02	+0'907	+0'390	-0'390	-0'542	+0'874	-0'970
39	+8'31		-0'972	+0'043	-0'044	+0'381	+1'509	-0'904
40	-6'72	-6'15	-0'060	+0'998	-0'998	-0'251	-3'254	-0'986
41	+14'26		-0'880	-0'034	+0'036	+0'582	+2'020	-0'915
42*	+15'00		-0'851	-0'255	+0'257	+0'519	+2'630	-0'916
43	-11'56		+0'778	-0'553	+0'551	-0'396	+1'110	-0'924
44	+6'03		-0'306	+0'942	-0'942	+0'308	-1'250	-0'889
45	+4'85		-0'224	+0'969	-0'969	+0'267	-1'406	-0'889
46	+8'85		-0'833	-0'350	+0'351	+0'367	+2'442	-0'895
47	+12'04		-0'860	+0'336	-0'337	+0'498	+1'048	-0'925
48	-10'46	-10'12	+0'882	+0'249	-0'247	-0'385	-2'399	-0'886
49	-12'31	-12'50	+0'830	-0'409	+0'410	-0'457	-0'886	-0'886
50	+5'61		-0'524	-0'813	+0'814	+0'343	+3'219	-0'907
51			Rejected					
52	+9'62		-0'773	-0'525	+0'526	+0'400	+0'003	-0'909
53	-8'50	-8'62	+0'311	-0'949	+0'949	-0'363	+3'228	-0'928

The best thanks of the authors are due to Dr. A. C. D. Crommelin and to Mr. T. Lewis for kindly communicating Greenwich results and time-signal errors.

Woolwich Polytechnic:
1915 July.

Observations of Comet Mellish (1915a) made with the 10-inch Refractor of the University Observatory, Utrecht, Holland.
By J. van der Bilt.

Date.	Utrecht Mean Time.			App. R.A.	Parallax Factor.	App. Decl.	Parallax Factor.	No. of Obs.	
	h	m	s	h m s				R.A.	Decl.
1915									
Mar. 19	14	7	13	17 49 30.42	9.489 _n	+ 0° 2' 45".6	0.841	12	6
21	13	18	58	17 51 57.97	9.528 _n	- 0 10 35.2	0.841	12	6
25	14	18	4	17 56 59.00	9.454 _n	- 0 40 25.5	0.843	10	5
27	13	32	44	17 57 41.40	9.501 _n	- 0 51 38.6	0.843	12	3
31	13	54	46	18 4 25.23	9.464 _n	- 1 31 52.5	0.846	20	5
Apr. 7	13	17	56	18 13 9.03	9.488 _n	- 2 47 2.1	0.849	10	5
12	13	6	45	18 19 29.19	9.486 _n	- 3 54 33.6	0.852	10	5
14	14	8	36	18 22 6.56	9.376 _n	- 4 26 21.7	0.859	10	5
17	13	47	13	18 25 59.56	9.404 _n	- 5 18 16.0	0.861	20	5
19	12	58	44	18 28 35.46	9.474 _n	- 5 56 24.2	0.858	20	5
21	12	41	22	18 31 15.58	9.490 _n	- 6 38 39.8	0.858	12	6
27	12	55	58	18 39 40.50	9.453 _n	- 9 13 32.4	0.869	6	3
May 2	13	16	20	18 47 18.93	9.399 _n	- 12 3 33.1	0.881	10	5
7	13	35	3	18 55 52.91	9.336 _n	- 15 45 22.9	0.895	8	4
10	14	7	21	19 1 42.69	9.218 _n	- 18 32 3.8	0.910	10	5
11	13	46	45	19 3 45.33	9.288 _n	- 19 33 0.0	0.908	20	10
14	14	44	27	19 10 39.39	9.000 _n	- 23 4 19.9	0.926	8	4

Comparison Stars.

Date.	Mean R.A.			Red. to Date.	Mean Decl.			Red. to Date.	Reference.
	h	m	s	s	°	'	"	"	
Mar. 19	17	48	30.48	+1.27	- 0	1	7.7	-16.6	A. G. Nic. 4435
21	17	50	43.41	+1.32	- 0	12	45.2	-16.4	„ 4446
25	17	54	17.10	+1.45	- 0	34	29.4	-16.1	„ 4462
27	17	58	7.88	+1.49	- 0	55	4.8	-15.9	Alg. ph., Cl. 971, No. 47
31	18	4	8.68	+1.56	- 1	29	45.1	-15.4	A. G. Nic. 4500
Apr. 7	18	13	55.48	+1.76	- 2	39	20.8	-14.2	„ Strsb. 6121
12	18	17	8.23	+1.89	- 3	54	54.2	-13.5	„ „ 6141
14	18	24	35.98	+1.91	- 4	30	10.7	-12.8	„ „ 6181
17	18	26	22.80	+2.00	- 5	4	16.9	-12.2	„ „ 6193
19	18	28	49.79	+2.06	- 5	58	30.0	-11.6	„ „ 6206
21	18	32	8.52	+2.12	- 6	29	31.9	-11.1	„ Ott. 6233
27	18	37	37.17	+2.29	- 9	8	5.4	-9.6	„ „ 6279
May 2	18	44	42.01	+2.47	- 11	53	6.0	-7.7	„ Camb. 6460
7	18	55	6.68	+2.65	- 15	49	4.1	-5.6	„ Wash. 7023
10	19	4	11.29	+2.74	- 18	37	26.9	-3.9	Arg.-Æltz. 19 135/36
11	19	3	17.00	+2.78	- 19	25	27.0	-3.6	Paris 25357
14	19	8	50.88	+2.94	- 23	4	36.5	-1.8	Arg. Gen. Cat. 26329

Notes.

- Mar. 19. Brightness, in 3'' finder, about 8^m.9 (0^m.2 fainter than B.D. - α 3374). The comet presented a very foggy nucleus surrounded by a bright, irregular coma.
- Apr. 14. Development of tail in an almost exactly western direction. Symmetrically curved coma.
- Apr. 21, May 7. Haze; observation difficult.
- May 10. The comet showed a secondary nucleus, preceding the bright one about 1^s.3 and being a little north of it.
- May 11. The secondary nucleus preceded about 1^s.8; it looked fainter than the day before, but clouds and haze rendered this observation rather doubtful.
- May 14. Relatively to the bright nucleus, the secondary one was located as follows:— $\Delta\alpha = -2^s.0$ $\Delta\delta = +7''$.

Utrecht:
1915 July 12.

Observations of Comet 1915a (Mellish). By Ernest H. Beattie.

The following positions have been obtained here with a 6½-inch Grubb equatorial refractor, with filar micrometer and recording chronograph :—

				Stars Assumed.					
				α			δ		
				h	m	s	$^{\circ}$	'	"
G. M. T. 1915 May 11	d	h	m s				19	3	47.91
							- 19	5	20
A. G. C. 26204 ($7\frac{3}{4}$)									
Aberration							$\Delta\alpha$	- 57.36	$\Delta\delta$ - 42
							19	2	50.55
							- 19	6	2
							$\pi(\alpha)$	- 0.47	$\pi(\delta)$ - 4
							19	2	50.08
							- 19	6	6
G. M. T. 1915 June 6	d	h	m s				22	25	53.43
							- 69	32	11
A. G. C. 30671 (7)									
Aberration							$\Delta\alpha$	- 52.54	$\Delta\delta$ - 9 55
							22	25	0.89
							- 69	42	7
							$\pi(\alpha)$	+ 3.39	$\pi(\delta)$ - 9
							22	25	4.28
							- 69	42	16
G. M. T. 1915 June 7	d	h	m s				23	19	2.03
							- 72	37	36
A. G. C. 31675 ($7\frac{1}{4}$)									
Aberration							$\Delta\alpha + 11$	3.04	$\Delta\delta$ + 3 42
							23	30	5.07
							- 72	28	54
							$\pi(\alpha)$	+ 2.95	$\pi(\delta)$ - 15
							23	30	8.02
							- 72	29	9

				Stars Assumed.			
				α		δ	
				h	m	s	
G. M. T. 1915 June 19	d	h	m	s			
	19	21	50	6.3			
<i>A. G. C.</i> 5308 (7½)							
Aberration							
				- 4	6.0		
				21	46	0.3	
G. M. T. 1915 June 24	d	h	m	s			
	24	21	28	11.78			
<i>A. G. C.</i> 6268 (6.4)							
Aberration				- 4	36.89		
				21	23	34.89	
G. M. T. 1915 June 29	d	h	m	s			
	29	21	41	9.0			
<i>A. G. C.</i> 6638 (6.5)							
Aberration				- 5	15.2		
				21	35	53.8	
G. M. T. 1915 June 30	d	h	m	s			
	30	20	36	7.0			
<i>A. G. C.</i> 6764 (8.0)							
Aberration				- 5	21.9		
				20	30	45.1	
G. M. T. 1915 July 1	d	h	m	s			
	1	21	15	57.15			
<i>A. G. C.</i> 6861 (7.1)							
Aberration				- 5	27.50		
				21	10	29.7	

				α		δ	
				h	m	s	
				4	37	50.24	- 62° 32' 24.7"
				$\Delta\alpha$	+ 1	48.03	$\Delta\delta$ + 36.4
				4	39	38.27	- 62 31 48.3
				$\pi(\alpha)$	+ 1.42	$\pi(\delta)$	- 4.9
				4	39	39.69	- 62 31 53.2
				5	20	52.16	- 56 12 21.5
				$\Delta\alpha$	- 6	8.09	$\Delta\delta$ + 7 54.0
				5	14	44.07	- 56 4 27.5
				$\pi(\alpha)$	+ 1.25	$\pi(\delta)$	- 11.2
				5	14	45.32	- 56 4 38.7
				5	36	20.51	- 50 40 54.3
				$\Delta\alpha$	- 1	35.16	$\Delta\delta$ - 4 15.1
				5	34	45.35	- 50 45 9.4
				$\pi(\alpha)$	+ 0.92	$\pi(\delta)$	- 10.2
				5	34	46.27	- 50 45 19.6
				5	41	26.75	- 49 52 24.2
				$\Delta\alpha$	- 3	58.59	$\Delta\delta$ + 1 7.2
				5	37	28.16	- 49 51 17.0
				$\pi(\alpha)$	+ 1.05	$\pi(\delta)$	- 8.0
				5	37	29.21	- 49 51 25.0
				5	46	9.28	- 48 56 25.1
				$\Delta\alpha$	- 5	41.11	$\Delta\delta$ + 51.9
				5	40	28.17	- 48 55 33.2
				$\pi(\alpha)$	+ 0.92	$\pi(\delta)$	- 9.2
				5	40	29.09	- 48 55 42.4

The identification of the stars was in some cases difficult, owing to the large correction for refraction. Full data are given to admit of the checking of reduction as desired.

Co-ordinates of observatory, E. 10^h 4^m 55^s.73, S. 33° 50' 11".

*Private Observatory, Mosman,
near Sydney, Australia:
1915 August 9.*

Observations of Comet 1915a (Mellish). By Richard Craven,
Commander T.S.S. *Indrapura*.

(Communicated by the Secretaries.)

Herewith are particulars of a comet observed by me when travelling in T.S.S. *Indrapura* from Cape Town, S.A., to Melbourne, Australia.

"Monday June 7th, 1915, ship in latitude $45^{\circ} 24'$ South and longitude $55^{\circ} 11'$ East, at 7.17 p.m. app. time at ship, I observed a comet (very clear indeed) heading about S.W. true, with a tail about 6° long trailing N.E. The eye of the comet bore S. $9\frac{1}{2}^{\circ}$ E. true. The altitude was nearly $28^{\circ} 30'$, G.M.T. $6^{\text{d}} 3^{\text{h}} 39^{\text{m}} 27^{\text{s}}$.

"Tuesday June 7th, 1915, this same comet was observed at 5.19 a.m. app. time at ship, bearing South true. Altitude about $63^{\circ} 10'$, G.M.T. $7^{\text{d}} 13^{\text{h}} 21^{\text{m}} 20^{\text{s}}$. Ship's position by stars at 5.55 a.m. was lat. $45^{\circ} 48\frac{1}{2}'$ S., long. $58^{\circ} 8'$ East, steering S. 81° E. true, speed 12.7 knots."

Although seen several times in the southern sky as a "Circumpolar" comet, the subsequent weather was too misty and cloudy to get good bearings, etc. The comet when first seen was very clear and easily seen with the naked eye.

On the Conjunctions of Stars with the Moon, recorded by Ptolemy.

By J. K. Fotheringham, M.A., D.Litt.

In a note on this subject contributed to the *Monthly Notices* for May (lxxv. p. 589), Mr. Nevill expresses the opinion that the results appear to be too discordant to be of much value for determining the secular acceleration of the Moon. In the paper which Miss Longbottom and I contributed to the *Monthly Notices* for March (lxxv. p. 393) the probable error of the result is deduced from the discordances. The probable error is large as compared with that deduced from lunar eclipses, but, as we suggested on p. 378, if a secular acceleration of the Sun is regarded as possible, the lunar eclipses do not give us the sidereal acceleration of the Moon, and the result derived from the conjunctions is the best available.

Mr. Nevill also finds that the observed epochs as deduced by Schjellerup differ materially from those given by us, and infers that this uncertainty as to the true times must still further decrease the value of the observed conjunctions. The differences in the observed epochs are mainly due to the interpretation of the phrases *ώρας ἀρχούσης* and *ώρας ληγούσης*. Schjellerup took these to refer to the exact beginning and end respectively of the hour to which they refer. Miss Longbottom and I, as we explained on p. 380,

understood them to refer to the first and last thirds respectively of the hour, and, where the phraseology did not indicate the time more exactly, we computed for the middle of the third part to which reference was made. In our discussion of the weighting of the observations (pp. 390-393) this uncertainty as to the true time was treated as cause (1) of error, and was duly allowed for in the final weighting of the observations. It was found that its inclusion did not affect either the value derived for the secular acceleration of the Moon or the probable error of the result.

1915 *July* 28.

LIST OF ADDITIONS
TO THE LIBRARY
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JUNE 1914 TO JUNE 1915.

An asterisk () indicates that the work is an excerpt.*

Abbadia, Observatoire :

Catalogue de 13532 Étoiles, comprises entre $+5^{\circ} 15'$ et $-3^{\circ} 15'$ (Zone photographique d'Alger) . . . réduites à 1900^o.
(*Observatory.*) 4to. Hendaye, 1914

Aitken (Robert Grant) :

*Measures of Double Stars made with the thirty-six-inch and twelve-inch refractors of the Lick Observatory, from June 1895 to December 1912.
(*Author.*) Berkeley, Cal., 1914

Algiers, Observatoire :

Carte photographique du Ciel. Eighteen charts. Zone -1° , $+1^{\circ}$, $+3^{\circ}$.
(*French Minister of Public Instruction.*)

Allegheny Observatory :

Publications. Vol. 3, No. 9-18.
(*Observatory.*) 4to. Lancaster, Pa., 1914

American Academy of Arts and Sciences : *see* Boston.

American Journal of Mathematics. Edited by Frank Morley. Published under the auspices of the Johns Hopkins University. Vol. 36, No. 3, 4; Vol. 37, No. 1, 2.
(*Editors.*) 4to. Baltimore, 1914-1915

American Journal of Science. Editor E. S. Dana [and others]. Fourth series, Vol. 38, 39 (No. 223-233).
(*Editors.*) 8vo. New Haven, 1914-1915

Amsterdam, Koninklijke Akademie van Wetenschappen :
——: Verslagen van de gewone Vergaderingen der Wis- en Natuurkundige Afdeeling, 1913-1914. Deel 22, pt. 1, 2.
(*Academy.*) 8vo. Amsterdam, 1913-1914

- Amsterdam, Koninklijke Akademie van Wetenschappen**
 —continued :
 — : Proceedings of the section of Sciences, Vol. 16, pt. 1 and 2.
 (Academy.) 8vo. Amsterdam, 1913-1914
 — : Jaarboek, 1913.
 (Academy.) 8vo. Amsterdam, 1914
- Antwerp, Société d'Astronomie :**
 — : Mémoires, 1.
 (Editors.) 8vo. Anvers, 1914
 L'Éclipse de Soleil du 17 Avril, 1912 : Observations et résultats.
 — : Gazette Astronomique, éditée par la Société d'Astronomie
 d'Anvers. 7me. Année, 1914, No. 9 (No. 82).
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- Arcetri, Reale Osservatorio :**
 Pubblicazioni del R. Istituto di studi superiori pratici e di
 perfezionamento, fasc. 32.
 (Observatory.) 4to. Firenze, 1914
 A. Abetti. Osservazioni astronomiche fatte . . . 1913.
- Astronomical and Astrophysical Society of America :**
 Publications, vol. 2, pt. 1.
 (Prof. W. J. Hussey.) 8vo. Ann Arbor, 1912
- Astronomical Herald (the).** Published by the Astronomical
 Society of Japan [in Japanese]. Vol. 6, No. 12 ; Vol. 7,
 No. 1-12.
 (Society.) 4to. 1914-1915
- Astronomical Journal.** Founded by B. A. Gould. Vol. 28,
 29 (No. 668-677).
 (Editor.) 4to. Boston, 1914-1915
- Astronomie (L').** See Paris, Société Astronomique de
 France.
- Astronomische Mitteilungen.** Gegründet von Rudolf Wolf :
 herausgegeben von A. Wolfers. No. 105.
 (Editor.) 8vo. Zürich, 1915
- Astronomische Nachrichten.** Begründet von H. C. Schu-
 macher : herausgegeben von H. Kobold. Band 198-201
 (No. 4739-4801).
 (Editor.) 4to. Kiel, 1914-1915
- : Literarisches Beiblatt zu den Astronomischen Nachrichten.
 No. 22, 23.
 (Editor.) 4to. Kiel, 1914
 (Another Copy purchased.)
- Astronomischer Jahresbericht.** Begründet von W. F. Wis-
 licenus. . . . Bearbeitet im Kgl. Astronomischen Rechen-
 Institut zu Berlin. Band 15. Die Literatur des Jahres,
 1913.
 (K. Astron. Rechen-Institut, Berlin.) 8vo. Berlin, 1914

- Astrophysical Journal (the).** An International Review of spectroscopy and astronomical physics. Edited by G. E. Hale [and others]. Vol. 39, No. 5-Vol. 41, No. 3. (Editors.) 8vo. Chicago, 1914-1915
(Another Copy purchased.)
- Athenæum (the).** Journal of English and foreign literature, science, the fine arts, music, and the drama, 1914-1915. (No. 4521-4572). (Editor.) 4to. London, 1914-1915
- Auwers (G. F. J. Arthur):**
Bearbeitung der Bradley'schen Beobachtungen an den alten Meridianinstrumenten der Greenwicher Sternwarte. Band 3 : der Sternecatalog. (Prof. Auwers.) 4to. Leipzig, 1914
- Backhouse (Thomas William):**
Publications of West Hendon House Observatory, Sunderland. No. IV. (T. W. Backhouse.) 4to. Sunderland, 1915
- Ball (Robert Stawell):**
Reminiscences and letters of Sir Robert Ball. Edited by his son, W. Valentine Ball. (Purchased.) 8vo. London, 1915
- Barcelona, Sociedad Astronomica:**
Boletín, Año 5, 6. (No. 42-50.) (Society.) 8vo. Barcelona, 1914-1915
- Barrett (John):**
An enquiry into the Origin of the Constellations that compose the Zodiac, and the uses they were intended to promote. (E. W. Maunder.) 8vo. Dublin, 1800
- Basel, Naturforschende Gesellschaft:**
Verhandlungen; Band 25. (Society.) 8vo. Basel, 1914
- Batavia, Koninklijke Natuurkundige Vereeniging in Nederlandsch-Indië:**
Natuurkundig Tijdschrift voor Nederlandsch-Indië. Deel 73. (Society.) 8vo. Weltevreden, 1914
- Batavia, Royal Magnetical and Meteorological Observatory:**
Observations . . . published by order of the Government of Netherlands India. Vol. 34. (Observatory.) 4to. Batavia, 1914
- Berlin, Königlich Preussische Akademie der Wissenschaften:**
Abhandlungen: Physikalisch-mathematische Classe. Jahrgang 1914, No. 2. (Academy.) 4to. Berlin, 1914

Berlin, Königliche Sternwarte :

Beobachtungs Ergebnisse, Heft 16.

(Observatory.)

4to. Berlin, 1914

Mittlere Örter von 2338 Vergleichsternen für 1865 '0.

Berlin, Vereinigung von Freunden der Astronomie und kosmischen Physik :

Mitteilungen, Jahrgang 24, Heft 4, 5.

(Purchased.)

8vo. Berlin, 1914

Besançon, Observatoire National Astronomique, Chronométrique et Météorologique :

— : Bulletin Chronométrique, 23.

(Observatory.)

4to. Besançon, 1912

— : Station Sismique.

(Observatory.)

4to. Tours, 1912

Bombay and Alibag Observatory :

Report of the Director for 1914.

(Observatory.)

fol. Bombay and Alibag, 1915

Bordeaux, Société des Sciences Physiques et Naturelles :

Procès-verbaux des séances, année 1912-1913.

(Society.)

8vo. Paris et Bordeaux, 1913

Boston, American Academy of Arts and Sciences :

Proceedings. Vol. 50, No. 1-3.

(Academy.)

8vo. Boston, Mass., 1914

British Association for the Advancement of Science :

Report of the 83rd meeting, held at Birmingham, 1913.

(Association.)

8vo. London, 1914

Brown's Nautical Almanac, Harbour and dock guide, and daily tide tables for 1915.

(Editor.)

8vo. Glasgow [1914]

Brussels, Société Belge d'Astronomie :

Ciel et Terre : Bulletin de la Société Belge d'Astronomie, et Revue populaire d'astronomie, de météorologie et de physique du globe. Année 35, No. 5, 6.

(Society.)

8vo. Bruxelles, 1914

Bulletin Astronomique. Fondé en 1884 par E. Mouchez et F. Tisserand. Publié par l'Observatoire de Paris. Tome 31, No. 6-12 ; Tome 32, No. 1, 2.

(Purchased.)

8vo. Paris, 1914-1915

Bulletin des Sciences Mathématiques. Rédigé par G. Darboux et E. Picard. Série 2. Tome 38, No. 6-12 ; Tome 39, No. 1-5.

(Editors.)

8vo. Paris, 1914-1915

Calcutta, Astronomical Society of India :

Journal, Vol. 4, No. 6.

(Society.)

8vo. Calcutta, 1914

Cambridge Observatory :

Annual Report of the Observatory Syndicate, 1913-1914.

(Observatory.)

4to. Cambridge [1914]

Cambridge Philosophical Society :

— : Proceedings, Vol. 17, pt. 6 ; Vol. 18, pt. 1, 2.

(Society.)

8vo. Cambridge, 1914-1915

— : Transactions, Vol. 22, pt. 5-7.

(Society.)

4to. Cambridge, 1914-1915

Cambridge University ; Solar Physics Observatory :

First Annual Report of the Director . . . to the Solar Physics Committee, 1913-1914.

(Observatory.)

4to. Cambridge, 1914

Canada, Royal Society :

Transactions, Section III. (Mathematical, Physical, and Chemical Sciences). Series 3, Vol. 7 ; Vol. 8, 1914 June, Sept., Dec., 1915 March.

(Society.)

8vo. Ottawa, 1914-1915

Cape of Good Hope, Royal Observatory :

Annals, Vol. 11, pt. 3 ; Vol. 12, pt. 5.

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4to, London, 1914

Vol. 11, pt. 3. Discussion of observations of Circumpolar Stars.

,, 12, ,, 5. De Sitter : Orbital planes of Jupiter's satellites.

Cape Town, Royal Society of South Africa :

Transactions, Vol. 4, pt. 2.

(Society.)

8vo. Cape Town, 1914

Cape Town, South African Association for the Advancement of Science :

The South African Journal of Science, Vol. 10, No. 9-14 ; Vol. 11, No. 1-8.

(Association.)

8vo. Cape Town, 1914-1915

Catania, Società degli Spettroscopisti Italiani :

Memorie . . . Fondata da P. Tacchini : pubblicazione mensile continuata per cura di A. Riccò. Serie 2, Vol. 3, Disp. 5-12 ; Vol. 4, Disp. 1-4.

(Society.)

4to. Catania, 1914-1915

Chatham, Royal Engineers' Institute :

The Royal Engineers' Journal, Vol. 20, 21.

(Institute.)

8vo. Chatham, 1914-1915

Chicago, Society for Practical Astronomy :

The Monthly Register, Vol. 6, No. 4-8 ; Vol. 7, No. 1-3.

(The Editor.)

8vo. Chicago, 1914-1915

Ciel et Terre. See Brussels, Société Belge d'Astronomie.

Clancey (John Charles):

A series of Monthly and General Star Maps, chiefly for use in latitude 20° N.

(*Author.*)

4to. 1915 [1914]

Copenhagen, Kongelige Danske Videnskabernes Selskab:

—: Oversigt over det K. Danske Videnskabernes Selskabs Forhandler. 1914, No. 3-6; 1915, No. 1.

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